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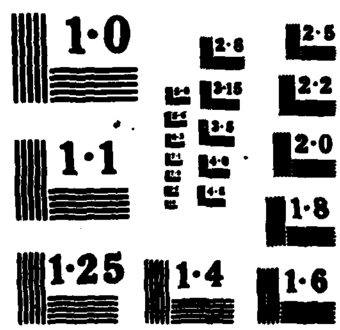
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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CG-D-13-85	A158 200	
4. Title and Subtitle CONCEPTUAL DESIGN OF FOUR SURFACE EFFECT SHIPS FOR U. S. COAST GUARD APPLICATIONS		5. Report Date MAY 1985 6. Performing Organization Code
7. Author(s) NAVAL SEA SYSTEMS COMMAND (CODE 05R)		8. Performing Organization Report No.
9. Performing Organization Name and Address NAVAL SEA SYSTEMS COMMAND SHIP DESIGN & ENGINEERING RESEARCH & DEVELOPMENT OFFICE (CODE 05R) WASHINGTON, D. C. 20362		10. Work Unit No. (TRAIS) 11. Contract or Grant No. Z0099-2-05584/DTCG23-84-F-20051
12. Sponsoring Agency Name and Address UNITED STATES COAST GUARD OFFICE OF RESEARCH & DEVELOPMENT (G-DMT) WASHINGTON, D. C. 20593		13. Type of Report and Period Covered FINAL REPORT SEP 1982 - MAY 1985 14. Sponsoring Agency Code

15. Supplementary Notes

THIS REPORT WAS ORIGINALLY PREPARED BY NAVAL SEA SYSTEMS COMMAND UNDER CONTRACT NO. Z0099-2-05584. THE REPORT WAS REFINED BY DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER, SURFACE EFFECT SHIP DIV. UNDER CONTRACT NO. DTCG23-84-F-20051.

16. Abstract

THE REPORT PRESENTS THE DEVELOPMENT OF SURFACE EFFECT SHIP DESIGN CONCEPTS AS POSSIBLE FUTURE EQUIVALENTS OF EXISTING WHEC, WMEC, WLB AND WPC U. S. COAST GUARD SHIP TYPES.

THE MAIN BODY OF THE REPORT PRESENTS THE BACKGROUND, REQUIREMENTS, AND THE ANALYSIS RELATED TO THE CONCEPT DESIGN DEVELOPMENTS. A TECHNICAL APPENDIX PRESENTS TECHNICAL DESCRIPTIONS, DESIGN CHARACTERISTICS AND LAYOUT DRAWINGS FOR EACH OF THE FOUR SHIP TYPES. Originator-supplied keywords:

17. Key Words		18. Distribution Statement
SURFACE EFFECT SHIP, SES, WEIGHTS, FEASIBILITY DESIGN, STABILITY,	SHIP MOTIONS, PERFORMANCE, RANGE, ARRANGEMENTS, PROPULSION.	DOCUMENT IS AVAILABLE TO THE U. S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	390	

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METRIC CONVERSION FACTORS

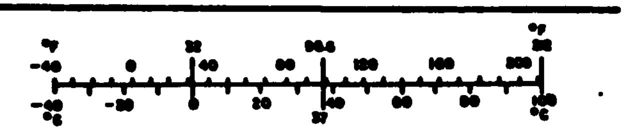
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ACKNOWLEDGEMENTS

The U. S. Coast Guard, Office of Research and Development wishes to thank the following individuals for undertaking the effort to update and refine this report:

Mr. Roy P. Treese
Mr. Allen G. Ford

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ABSTRACT

This report presents the development of surface effect ship design concepts as possible future equivalents of existing WHEC, WMEC, WLB, and WPC U.S. Coast Guard ship types.

The main body of the report presents the background, requirements, and the analysis related to the concept design developments. A technical appendix presents a concise technical description, design characteristics, and layout drawings for each of the four ship design concepts prepared through the course of the study.

1 / INTRODUCTION

This report presents the results of a study directed toward the development of Surface Effect Ship (SES) designs to satisfy the requirements related to four standard U.S. Coast Guard (USCG) Cutters, i.e.

High Endurance Cutter - WHEC
Medium Endurance Cutter _ WMEC
Buoy Tender - WLB
Patrol Craft - WPC

1.1 AUTHORIZATION

The study was prepared for the USCG by Departments Sea 05R47 and 50151 of the U.S. Naval Sea Systems Command (NAVSEA).

1.2 OBJECTIVE AND SCOPE

The objective of the study was to develop a conceptual SES design to be representative of an SES version of each of the standard USCG ship types identified above. The SES designs were to be developed only to the level of detail required for comparative evaluation of each SES design relative to USCG future needs. The scope of development therefore included the preparation of craft descriptions in terms of layout drawings, weight and performance estimates, motions characteristics and descriptive summaries.

1.3 ADVANTAGES OF THE SES

As recently demonstrated in the Operational Evaluation (OPEVAL) and Technical Evaluation (TECHEVAL) of the USCGC "Dorado" (WSES-1) and reported in Reference 1-1, the SES possesses certain inherent characteristics which could offer significant advantages in Coast Guard service.

a. <u>Energy Efficiency</u> -- The SES offers energy efficiency at high speed.

b. <u>Ride Quality</u> -- With active ride control, the SES maintains speed in rough water without excessive degradation of crew performance due to ship motions.

c. <u>Deck Operations</u> -- The rectangular deck areas provide efficient space utilization and space arrangements which facilitate ship handling, in-port and at-sea replenishment, and other deck operations. This feature also facilitates the installation of helicopter operation facilities.

d. <u>Stability</u> -- The relatively wide beam of the SES provides a high measure of metacentric stability for handling of heavy overside loads.

e. <u>Speed and Maneuverability</u> -- The SES offers capabilities of high speed and good maneuverability, both of which are essential for efficient search and rescue operations.

1.4 BACKGROUND

The point of departure for the study was the technology, engineering, and planning developed within the scope of the U.S. Navy 3000-Ton Surface Effect Ship (3KSES) program, augmented by recent SES technology developments.

The 3KSES program, as originally structured, specified an on-cushion speed requirement in excess of 80 knots in Sea State 3 with a range requirement in excess of 3000 nautical miles. The high speed requirement, together with the three thousand ton full load displacement constraint, dictated a low cushion length-to-breadth ratio (LC/BC = 2.4) hull configuration to permit the high on-cushion speed to be achieved in the post "hump", (wave making drag), operational regime. In addition, the high speed requirement led to the utilization of propulsion and lift systems consisting of six large gas turbine engines to provide the necessary power. The specified range, coupled with the installed power level, required that a large fraction of the full load displacement be allocated to fuel. The result of these considerations was to impose a severe constraint upon lightship weight and thus to require high-cost, minimum-weight approaches in the design of subsystems. The requirement for high on-cushion speed also established the need for minimized sidehull drag in waves, thereby entailing the selection of slender sidehull geometry. The slender sidehulls provided only a relatively small contribution to the total craft displacement, and resulted in the immersion of the main hull centerbody and thus to inefficient hydrodynamic performance in the off-cushion (hullborne) mode of operation.

Recent developments in surface effect ship technology have demonstrated that if a more moderate on-cushion speed goal is accepted, SES's with a higher length-to-breadth ratios (LC/BC) can operate in the subhump regime at speeds up to about 60 knots with significantly lower power levels and thereby improved operational economy. In addition, extensive model testing has shown that an increase in the buoyancy component of the sidehulls can be provided with little degradation of on-cushion performance, Also that increased sidewall displacement enables the surface effect ship to operate like a conventional catamaran in the hullborne mode and thereby cruise efficiently at speeds equivalent to the cruise speeds of conventional surface ships.

The increased buoyancy sidehulls also provide larger spaces and increased accessibility within each sidehull for the installation of main machinery and other shipboard equipment which allows the entire cross structure to be used for habitability spaces and the installation of mission related equipment.

The technical foundation for this study was largely provided by several exploratory studies conducted by the U.S. Navy Surface Effect Ship Project Office (PMS-304) which established that significant mission capability could be provided by SES's with full load displacements in the order of 100 to 2000 tons. Some of these studies are reported in References 1-2 and 1-3.

Valuable information for the study was also provided by the report on the OPEVAL and TECHEVAL of the USCGC "Dorado" (WSES-1) previously discussed. The "Dorado" was a 110-foot surface effect ship manufactured by Bell-Halter and subsequently purchased by the U.S. Navy in September 1980. The USCG leased the craft for an operational and technical evaluation over the period June through December in 1981. During this time the craft was commissioned as the USCG "Dorado" (WSES-1) and operated as a replacement for an 82-foot patrol boat (WPB). The Dorado was operated by Commander, Eigth Coast Guard District (CCCDEIGHT). The TECHEVAL was conducted by the Coast Guard Research and Development Center (R&DC) and the OPEVAL was essentially conducted by the Dorado crew.

The TECHEVAL included evaluations of deck area and internal volume, speed versus power, fuel consumption, towing capability, maneuverability, time to get underway and visibility from the pilothouse. Moment to heel, motion in waves, sail area; susceptability to slamming, performance in astern seas and watertight integrity, hull vibrations, handling of pollution gear, and boom handling were also studied, together with other secondary variables. The OPEVAL covered the areas of seakeeping, habitability, equipment arrangement, mission support capability, boat launching, survivability, inter-operability, logistics, maintainability

and anchoring. The general conclusion of the evaluation was that the Dorado performed very well during the OPEVAL period and was generally praised by the crew as a significant improvement over the patrol boats currently in USCG service. Few serious problems were experienced. Some design problems and areas of concern were identified through the evaluation and were attributed to the fact that the craft was not specifically designed for USCG service.

1.5 REPORT ORGANIZATION

Section 2 presents the technical approach selected for the implementation of the study. Section 3 presents the USCG requirements and boundary constraints which provided the foundation for the design development which is discussed in Section 4. Sections 5 and 6 address particular analyses related to hydrodynamic considerations and subsystem selection respectively. References are listed in Section 7. The descriptive material consisting of layout drawings, performance summaries, weight tables and text related to each of the four USCG surface effect ship designs prepared within the scope of the study are presented in four appendices.

2 /TECHNICAL APPROACH

The technical approach selected for the study is described in the following paragraphs. The approach was selected with the objectives of ensuring an orderly and thorough treatment of each area of investigation and providing a concise overall format for the documentation of the work accomplished within the course of the study.

The overall technical approach selected for the study is shown in Figure 2-1. As shown in Figure 2-1, the study was subdivided into four subtask areas of inquiry: (1) the definition of requirements for each USCG-SES design; (2) the development of ship design concepts; (3) analysis of the performance characteristics of the design concepts; and (4) the analysis of the key subsystems related to the design concepts with the objective of ensuring the selection of systems with a high measure of reliability and producibility. The technical approach followed within each of these subtask areas is discussed below. The work accomplished in each subtask area is documented in the subsequent sections of this report.

2.1 REQUIREMENTS DEFINITION

Design requirements and design constraints were identified through discussion with the USCG and the compilation of requirements descriptions for each USCG-SES design to be developed within the course of the study.

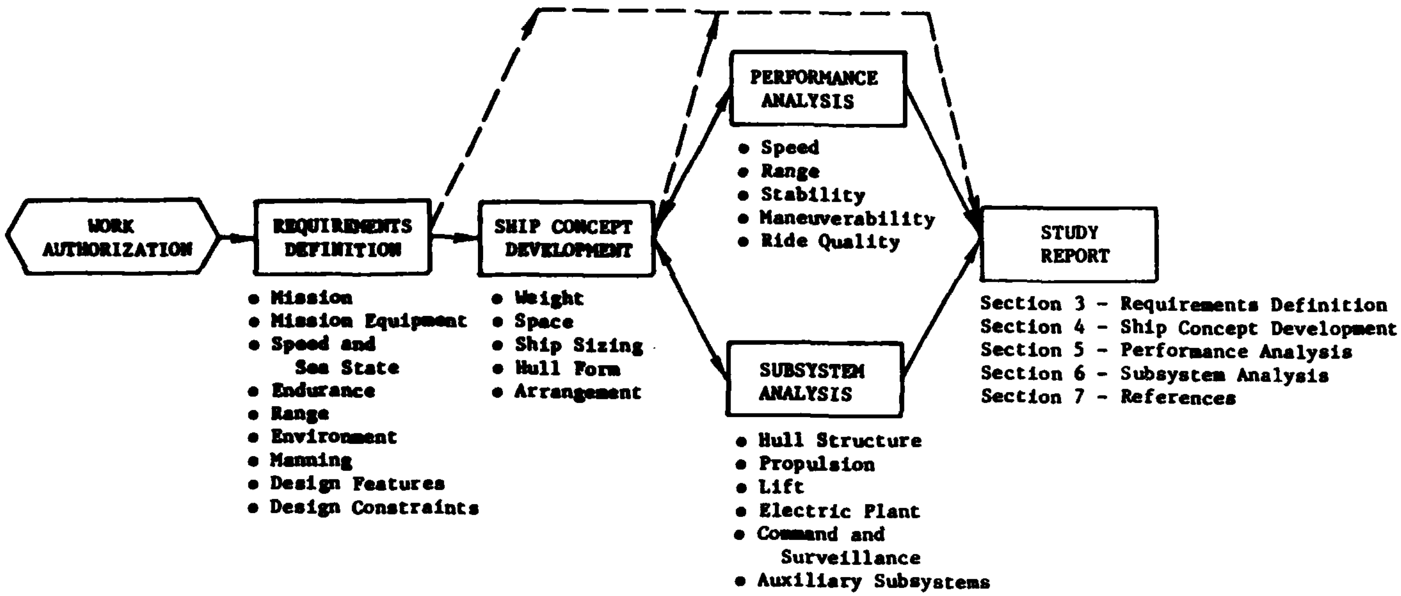


Figure 2-1. USCG-SES Study Technical Approach

For each design, requirements were identified in the following categories:

a. Mission -- Descriptions included both primary and secondary mission requirements.

b. Mission Equipment -- Some mission essential equipment items were identified and described in terms of weight and (whenever possible) volume requirements.

c. Speed and Sea State -- Cruise speed and dash speed requirements were defined relative to appropriate sea state conditions.

d. Endurance -- Endurance requirements were defined in terms of both total endurance and operational profiles (speed and time).

e. Range -- Range was defined in terms of endurance discussed in "d" above.

f. Operating Environment - Environmental requirements were described in terms of operational zone.

g. Complement - Personnel accommodation requirements were described in terms of both permanent crew and temporary duty personnel. The numbers of officers, petty officers, and enlisted personnel were specified.

h. Other Design Features - Special design features deemed essential or desirable were also identified. Items in this category typically consisted of damage resistance, fire fighting capability and hull construction material.

2.2 SHIP CONCEPT DEVELOPMENT

Ship concept development consists of the translation of the requirements and constraints into firm ship design concepts to provide a basis for performance analysis and the analysis of the various design related subsystems.

In this area, weight and space allocations were derived to provide a basis for ship sizing. Weight and space allocations were derived through reference to and analysis of the specified design requirement, the characteristics of existing, comparable USCG ships, prior surface effect ship studies, and for major components, manufacturers' catalog information.

Ship sizing and the selection of ship proportions was accomplished through parametric examination of weight, deck area, hull volume, speed and stability considerations.

Subsequent to ship size and proportion selection, hull form geometry, general arrangement and machinery arrangement layout drawings, were prepared to illustrate each design concept and validate the fundamental feasibility of the basic ship design.

2.3 PERFORMANCE ANALYSIS

Performance analysis was accomplished to support initial ship sizing and to define the performance characteristics of the ship design evolved through ship concept development. Analysis was performed to examine the characteristics of each ship design concept in the areas of speed/power/sea state and range relationships, maneuverability, on-cushion stability, hullborne intact stability, and damage stability.

The speed and range characteristics were derived by means of the NSRDC surface effect ship performance computer program. This program incorporates, in parametric form, the large body of speed/drag data derived through over 7,000 hours of large scale model testing and

analysis, such as documented in References 2-1 and 2-2. Preliminary performance estimates were subsequently confirmed by direct scaling of data derived through the testing of geometrically similar models reported in the reference documentation.

On-cushion stability and maneuverability characteristics were also assessed on the basis of model test data and analysis documented in References 2-3 and 2-4.

Hullborne intact and damage stability characteristics were assessed relative to the criteria for U.S. Naval surface ships (Reference 5-6).

2.4 SUBSYSTEM ANALYSIS

Subsystem studies were conducted with the objectives of ensuring the performance characteristics, practical feasibility, reliability and producibility of each ship design concept. In each case, the procedure was to: (1) define subsystem requirements, (2) survey available alternatives, and (3) select concepts and components which would provide the required capability at low cost and with little risk. The approach relative to major subsystems is discussed in the following.

2.4.1 HULL STRUCTURES -- The structural design for each USCG ship concept was developed by means of a thorough structural analysis at the preliminary design level of detail. Analysis was performed to verify the capability of the structure to withstand the major loads such as bending and hydrodynamic pressure expected to occur in service. Primary structural loads were derived from data provided by the many structural loads model tests conducted within other U.S. Navy high performance ship development programs such as documented in References 2-5 through 2-8. To the extent necessary, the capability of the structure to withstand certain local loads was also investigated. These analyses provide a high measure of confidence in the adequacy of the structural design. Also during the development of the proposed structural geometry, careful attention was specifically directed towards producibility considerations. Producibility

was identified as an essential design parameter in that the cost of hull construction is a major consideration in the total cost of high performance marine craft. Producibility features include:

a. A hull constructed almost entirely from flat plate material with little compound curvature and few thickness variations.

b. All areas highly accessible for welding and inspection.

The typical features of SES hull structures are shown in Figure 2.4-1. As shown in Figure 2.4-1, the basic hull structure consists of three major logitudinal continuous elements: (1) main deck, (2) wet deck, and (3) the port and starboard sidehulls. All longitudinal plating is stiffened by closely spaced, longitudinally continuous stiffeners. The hull is subdivided by transverse bulkheads spaced to satisfy arrangement requirements and to provide protection from progressive longitudinal flooding in the event of underwater hull damage.

Structural scantlings were determined on the basis of analysis considering (1) the normal loads resulting from seagoing operations such as longitudinal bending, transverse bending, and slamming pressure loads, and (2) the local structural loads resulting from crane hoisting and the installation of the mission related payload items.

The seagoing loads were derived from the results of the structural loads model tests conducted at NSRDC and referenced above. The extensive use of flat bar sections for the stiffening of longitudinal plating and the selection of other structural details reflects the result of the extensive testing of full-scale structural panels and structural elements and the producibility studies conducted within the U.S. Navy 3KSES program and documented in References 2-9 and 2-10.

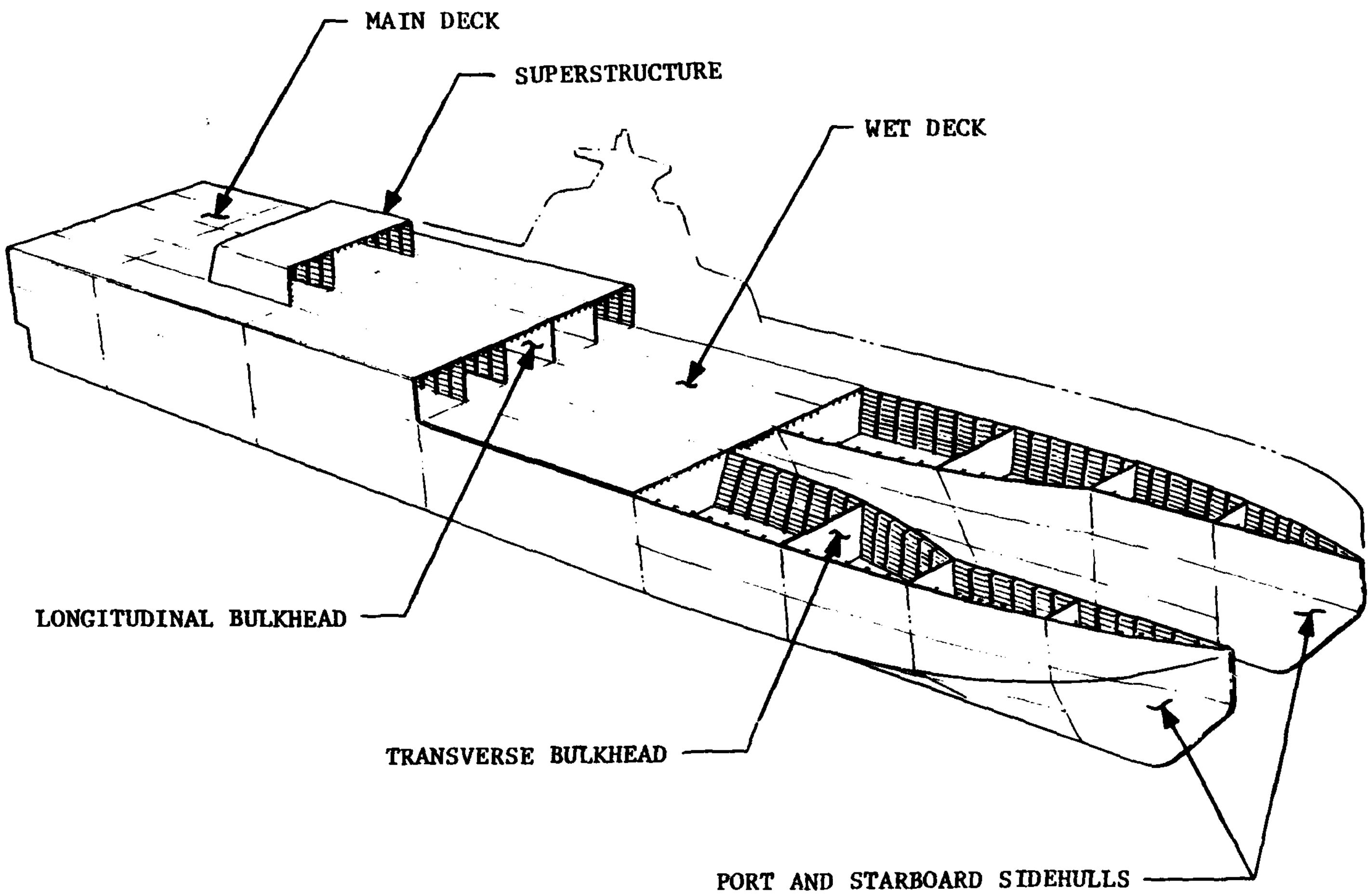


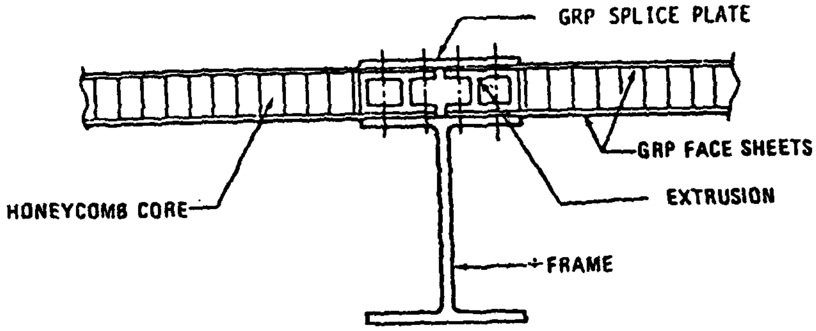
Figure 2.4-1. USCG Study - Typical Features of SES Hull Structure

Surface effect ship structures may be constructed of reinforced plastic, all-welded aluminum alloy or high strength low alloy steel. The selection is normally based upon ship size, cost and service considerations. In general, aluminum alloy is preferred for surface effect ships with less than 1500 tons full load displacement in that the use of steel in such craft incurs a weight penalty due to gauge thickness limitations. If, for particular reasons of acquisition economy or service requirements, steel is selected for the construction of craft of less than 1500 tons displacement, the weight penalty may be minimized through:

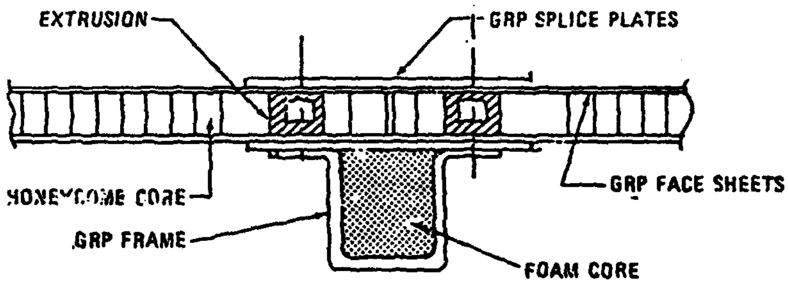
a. Careful analysis and optimization of hull scantlings in terms of stress, fatigue, and welding considerations.
b. The utilizatin of lower weight materials in non-priority structural areas.
c. The employment of high quality protective coating and cathodic protection to minimize structural degradation through corrosion.

Lightweight non-primary structural materials normally consists of integrally stiffened, cellular type, "honeycomb" panels designed and constructed to withstand the rigors of marine service. A typical arrangement for the installation of such panels is shown in Figure 2.4-2. The installations shown in Figure 2.4-2 has been successfully employed in the U.S. Navy SES-100B and in the SES-200.

2.4.2 PROPULSION AND LIFT SYSTEM -- The propulsion and lift systems were developed through careful analysis of the power necessary to satisfy the requirements for speed, range, and ride quality. Candidate prime movers were identified from among the limited number of options presently available. Gas turbine candidates were constrained to U.S. manufactured engines. Diesel engine candidates were constrained to high speed engines from both U.S. and Western European sources.



GRP SANDWICH PANEL SUPPORTED BY STEEL (OR ALUMINUM) FRAME



GRP SANDWICH PANEL SUPPORTED BY GRP FRAME

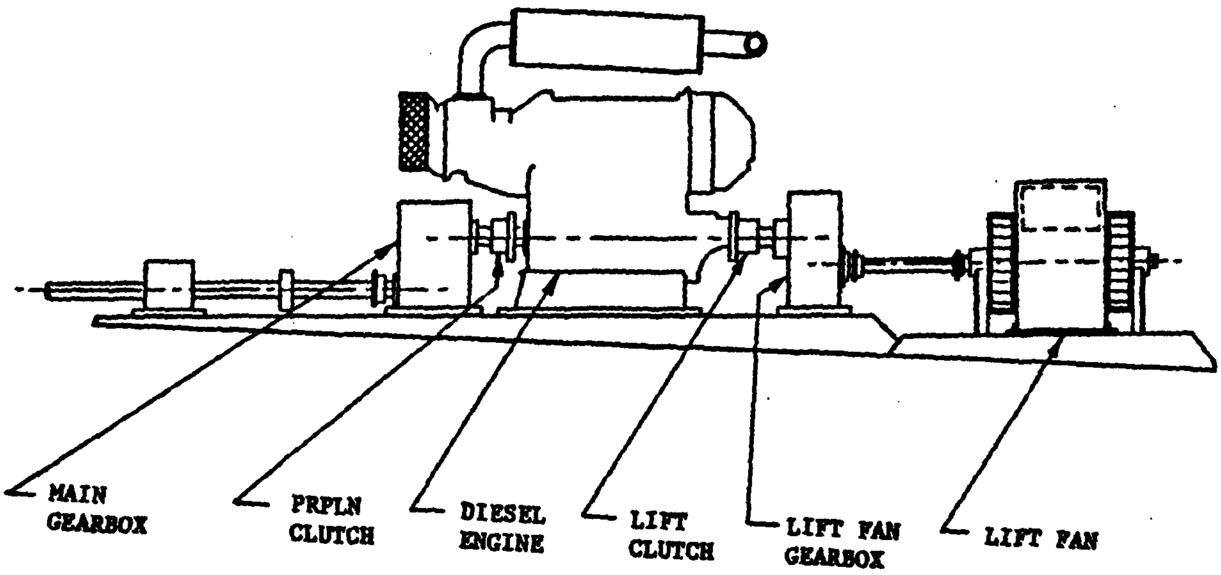
Figure 2.4-2. Lightweight Panel Non-Primary Structure

Potential machinery arrangement candidates were also noted. For example, prime movers may be used singly (two per shipset) or paired up. Likewise, propulsion and lift can be integrated, i.e., operated from a common prime mover, or can be separately powered. Typical machinery arrangement concepts are shown in Figure 2.4-3.

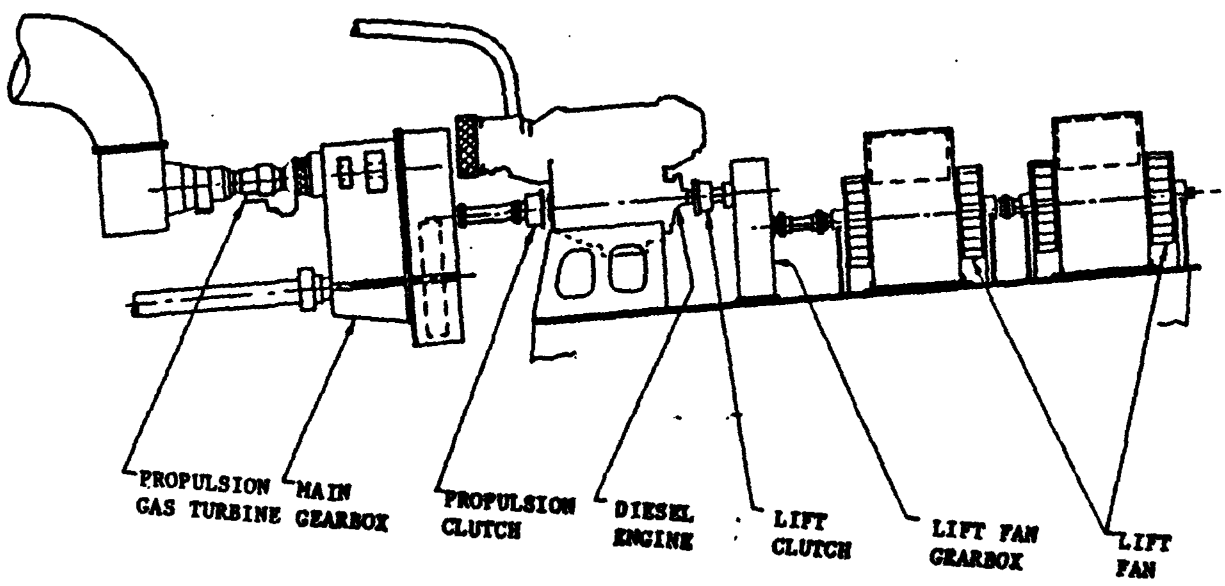
In the integrated propulsion system, each propulsion engine provides power to one propulsor and one or more lift fans. The lift fan(s) can be disconnected from the power train in event of fan failure of for hullborne (off-cushion) operation. System failure protection (redundancy) is provided in that the craft can still operate with reduced airflow in the event that one propulsion engine is inoperative.

2.4.2.1 Propulsion System — Candidate propulsors for SES applications include fixed pitch, controllable pitch, counter-rotating, partially-submerged and fully submerged propellers, together with pump-jet (ducted propeller) and waterjet propulsor types. The evaluation parameters normally employed in the selection process are propulsive efficiency, reliability, underwater noise, damage protection and cost.

The waterjet pump is an attractive SES propulsor from noise and damage protection viewpoints, but unacceptable for all USCG design concepts for reasons of poor low speed propulsive efficiency. The counter-rotating, ducted propeller types were considered to be undesirably complex and costly for the types of ships being considered within the study. An open water propeller was therefore, considered as the standard propulsor installation for the performance analysis and machinery arrangement development related to each of the four USCG-SES design studies. For performance analysis, data related to the "Newton-Rader" propeller type were used in that this propeller offers high efficiency and cavitation data above and below the cavitation index of all propeller installations required for the study. Propellers offering performance characteristics comparable with the Newton-Rader type are readily available from the Michigan Wheel Company. The analysis was accomplished on the basis of a



ALL DIESEL SYSTEM



CODOG SYSTEM

Figure 2.4-3. USCG Study-Typical Machinery Arrangement

fixed pitch propeller. It is believed that a controllable pitch propeller would be the optimum installation for all of the ship types investigated, however, detailed propeller optimization was considered to be beyond the scope of the present study.

Reduction gearing and transmission systems were derived to satisfy the requirements of the selected prime mover and propulsor installations. For SES design, the approach to reduction gearing selection is normally as follows. In the case of gas turbine and waterjet propulsion systems, the reduction gearing is generally designed as an integral part of the waterjet pump assembly. In diesel engine and propeller installations, the gearbox is normally selected from the range of standard marine gearbox designs specifically manufactured to interface with the prime mover. For gas turbine propeller propulsion systems and for integrated propulsion and lift systems special gearbox designs are ususally required.

The selection of directional control systems is largely influenced by the propulsor selected. In waterjet installations, a thrust vector/thrust reverser system is normally installed. In open propeller and ducted propeller installations, rudders with propeller reversing gear or reversible pitch propellers are normally employed. In that propeller type propulsions were selected for all USCG design concepts, rudders were identified as the standard approach for steering control.

2.4.2.2 Lift System -- The lift system of SES craft comprises three major elements:

a. Air supply to the lift cushion.
b. Ride control for minimization of heave motions.
c. Bow and Stern Seals.

The lift air supply is provided by fans driven by independent prime movers or from the main propulsion engines as previously discussed. The fans may be selected from axial flow, radial flow (centrifugal) or mixed flow

(combined axial and centrifugal) fan types. The mixed flow fan is generally employed in that this type provides better response to the cushion pressure fluctuations which occur due to the passage of sea waves through the cushion cavity.

Ride control is accomplished by modulation of the cushion air flow to minimize the pressure fluctuations resulting from the passage of sea waves. The flow control may be accomplished by either one or a combination of two means:

a. Fast response hydraulically actuated vent valves which modulate the cushion air flow through exhaust control.
b. Variable flow fans with hydraulically actuated inlet guide vanes (IGV's) which modulate the cushion air flow through control of the air supply.

The modulation of the vent valves or IGV's is performed in response to commands from a closed loop type ride control system (RCS) which senses variations in cushion pressure due to the passage of waves and controls the cushion discharge air flow to minimize pressure variations and hence the vertical accelerations of the craft.

Both methods of ride control have been demonstrated to be effective and have been refined over the past six years in the sea trials of the U.S. Navy XRI-D testcraft as documented in Reference 2-11.

For the USCG ship design, both variable flow fans and vent valves were selected for ride control in that this approach offered the advantages of minimized lift power and maximum state-of-the-art ride control performance.

Several bow and stern seal designs have been developed through various Navy SES development activities. The Transversely Stiffened Membrane (TSM) type bow seal was selected for the USCG ship designs in view of the excellent performance this seal has demonstrated in the U.S. Navy XR-1 surface effect testcraft. The seal is simply constructed from fabric

reinforced elastomeric sheet material with stiffeners cut from thin fiberglass reinforced plastic laminate. A simple three-loop type seal constructed from fabric reinforced elastomeric materials was selected as the stern seal for all four USCG SES designs. This type seal has demonstrated satisfactory performance on both the U.S. Navy SES-100B testcraft and the SES-200 craft.

2.4.3 ELECTRICAL SYSTEM — Diesel powered electrical generators were selected for all four USCG-SES designs on the basis of minimized total system weight (generators plus fuel) relative to the specified endurance requirements. These generators sized such that any two generators satisfy the maximum electric load requirement and a ring bus distribution system was considered the optimum electrical power plant configuration for all four designs.

2.4.4 COMMAND COMMUNICATION AND CONTROL -- The command communication and control system was addressed in terms of:

a. Military systems
b. Communication systems
c. Ship and machinery control systems

Systems in each of the above categories were defined to the level of detail appropriate to the concept design stage of development.

2.4.5 CRITICAL AUXILIARY SUBSYSTEMS -- All SWBS 500 elements were reviewed and assessed relative to a set of criteria selected to identify a level of critically (and hence priority) for investigation within the

scope of the study. Through this process, the auxiliary subsystems selected for special investigation were:

a. Sea water systems
b. Ship's fuel system
c. Steering systems
d. Helicopter recovery system

All other subsystems are considered non-critical and investigation of these systems was limited to the level of effort required to support ship concept definition and weight estimation. The outfit and furnishings system (SWBS 600) was considered non-critical and similarly constrained.

3 / REQUIREMENTS DEFINITION

The central requirement of this study was to develop four SES design concepts configured to be surface effect ship versions of 4 standard USCG cutters, i.e.:

High Endurance Cutter - WHEC
Medium Endurance Cutter - WMEC
Buoy Tender - WLB
Patrol Craft - WPC

3.1 DESIGN REQUIREMENTS

The design requirements for each of the craft listed above, as derived through discussion with USCG personnel, are provided in Tables 3.1-1 through 3.1-4.

3.2 DESIGN CONSTRAINTS

The constraints applicable to the concept design of the four ship configurations primarily consisted of the following:

a. Design constrained to use of existing SES technology.
b. Hull structures to be constrained to the use of existing readily available materials and established manufacturing techniques.
c. Machinery and auxiliary systems selected off-the-shelf components at existing power ratings to provide high measures of reliability and maintainability.

Table 3.1-1. WHEC Design Requirements

A. Missions:

ELT - Enforcement of Laws & Treaties
SAR - Search and Rescue
MER - Marine Environmental Response
MF - Military Preparedness
MSA - Marine Science Activities

B. Mission Equipment:

76mm Otto Melara w/MK 92 GFCS & ammo (10 Ltons)
(2) 6M RHI w/SPD (6.6 Ltons-(2)-19'x8'x4')
An/SPS 40B Air Search Radar
Helo Fuel (60 HRS 16 Ltons)
(2) 50 cal MG w/mounts and ammo (.5 Ltons)
(2) 40mm MG w/mounts and ammo (.5 Ltons)
C^3 and Navigation (20 Ltons)
CP Propellers

Stores (25.6 Ltons)
Water (28.5 Ltons)
Crew (42.4 Ltons)
CIWS (Vulcan Phalanx)
LAMPS I
Active/Passive Sonar (Towed Array)
SLQ-32
SRBOC

C. Speed vs. Sea State:

30 kts/Calm Water
28 kts/SS2
25 kts/SS3
20 kts/SS4

D. Endurance:

45 days

16,900 NM Range (Economical Cruise Speed)
3,400 NM @ 30 kts with 10% reserve fuel

E. N/A - to be governed by (D.)

F. Operating Environment:

Worldwide (no ice capability)

G. Complement:

169 Permanent Crew

15-Officers
12-CPOs
142-Enlisted

H. Other Design Features:

1. Refueling and replenishment at-sea
2. HH-52A and HH-65A operations and hanger capable
3. Rudder roll stabilization
4. External firefighting capabilities
5. Medical Support
6. HIFR
7. Meet USN 100 kt wind heel criteria
8. Survivability in SS6
9. 15-Yr hull life (aluminum or steel construction)
10. Expect 80% operation on-cushion

Table 3.1-2. WMEC Design Requirements

A. Missions:

ELT - Enforcement of Laws & Treaties

SAR - Search and Rescue

MER - Marine Environmental Response

MP - Military Preparedness

B. Mission Equipment:

Stores (6.1 Ltons)

C^3 Navigation (15.6 Ltons)

MK 75, 76mm Gun w/ammo and MK 92 GMS (10.0 Ltons)

(2) 40mm MG's w/mounts and ammo (.5 Ltons)

(2) 50 cal MG's w/mounts and ammo (.5 Ltons)

(2) 6M RHI w/SPD (6.6 Ltons-(2)-19'x8'x4')

Helo Fuel (45 Flt Hrs - 12 Ltons)

(2) - 500 KW Generators

(1) - 400 KW Emergency Generator

SRBOC (Super rapid blooming offboard chaff)

Water (14.6 Ltons)

Crew (21.6 Ltons)

LAMPS I

COMDAC - Automated CIC

6000 Gal/Day Evaporator

Towed Array Sonar

AN/SLQ-32

C. Speed vs. Sea State:

30 kts/SS2

25 kts/SS3

20 kts/SS4

35 kt dash capability (calm water)

D. Endurance:

21 days (504 hrs)

24 hrs @ top speed

480 hrs @ cruise speed

10% reserve fuel

E. N/A - to be governed by (D.)

F. Operating Environment:

Operating in temperate or southern waters (no ice capability) within 400 miles of land.

G. Complement:

90 Permanent Crew

12-Officers

9-CPOs

69-Enlisted

H. Other Design Features:

1. External Fire Fighting Capability (125 psi)
2. Available ride control systems for improving ride quality
3. Ability to meet USN 100 kt wind heel criteria
4. Survivability in SS6
5. Expect 80% operation on-cushion
6. 15-Yr hull life
7. Aluminum or steel construction
8. HIFR capability
9. Rudder roll stabilization
10. HH-65A operations and hanger capable

Table 3.1-3. WLB Design Requirements

A. Missions:

SRA - Short Range Aids To Navigation

SAR - Search and Rescue
ELT - Enforcement of Laws & Treaties
MER - Marine Environmental Response

B. Mission Equipment:

1600 FT^2 of deck space capable of supporting 50 Ltons
Hold capacity of 4,300 FT^3
(2) 6M RHI w/SPD (6.6 Ltons-(2)-19'x8'x4')
Storage of 10,000 gal. fuel and 15,000 gal. water for logistics
No Major weapons
20 Ltons crane capability
Stores (2.0 Ltons)
Crew (11.6 Ltons)
C^3 and Navigation (9.4 Ltons)

C. Speed vs. Sea State:

20 kts in Calm Water
18 kts in SS2
15 kts in SS3

D. Endurance:

10 - 14 days

1000-4000 NM with 10% reserve fuel

E. N/A - to be governed by (D.)

F. Operating Environment:

Occasional transit of ice burdened waters in Great Lakes and 1st and 3rd CG Districts. Extended deployment and severe weather in the 14th and 17th Goast Guard Districts.

G. Complement:

48 Permanent Crew

4-Officers
2-CPOs
42-Enlisted

H. Other Design Features:

1. Minimum freeboard at buoy deck (less than 5')
2. 360 deg vision for OOD
3. Remote steering and engine control station
4. Largest buoy 9x38 (LGR)=19,400 #'s + chain + (Weight of water if flooded)
5. Good low speed maneuverability
6. 14 Ft maximum draft
7. 20-Yr hull life
8. Steel construction
9. Survivability in SS6
10. Operate through SS4

Table 3.1-4. WPC Design Requirements

A. Missions:

ELT - Enforcement of Laws & Treaties
SAR - Search and Rescue
MP - Military Preparedness
SRA - Short Range Aids to Navigation
MER - Marine Environmental Response

B. Mission Equipment:

Stores (3.0 Ltons)	6M RHI w/single prop diesel (3.3 Ltons-19'x8'x4')
Water (3.0 Ltons)	2-50 cal. M60 w/mounts & ammo (.5 Ltons)
Crew (4.7 Ltons)	Towline (.5 Ltons-3'x3'x3')
C3 and navigation (4.0 Ltons)	Towing bitt (.3 Ltons-1'x3'x3')
30mm w/ammo & GFCS (5.0 Ltons)	Small arms locker (.1 Ltons-6'x2'x3')
Safe (.3 Ltons-3'x4'x3')	Desalinator (SW-600) (.1 Ltons- 4'x2'x2')
3 - P60 pumps (.5 Ltons)	Pyro locker (.1 Ltons-3'x4'x5')

C. Speed vs. Sea State:

30 kts/SS2
25 kts/SS3
20 kts/SS4

35 kt dash capability (calm water)

D. Endurance:

7 days (168 hrs.)

24 hrs @ a speed of 30 kts
144 hrs @ cruise speed (12 kts)
10% reserve fuel

E. N/A - to be governed by (D.)

F. Operating Environment:

Be able to operate 90% of the time in U.S. coastal waters south of 38N within 300 miles of land (no ice capability)

G. Complement:

24 Permanent Crew

2-Officers
3-CPOs
19-Enlisted

H. Other Design Features:

1. Available ride control system for improving ride quality
2. USN 2 compartment intact and damage stability
3. External fire fighting capability (125 psi)

4 / SHIP CONCEPT DEVELOPMENT

This section presents the considerations addressed in the development of the SES design concepts for each of the specified USCG missions.

4.1 SHIP SIZING

Ship proportions were developed to satisfy the weight and space requirements derived for each of the four craft designs and the speed and range requirements specified in Section 3.

For any given speed and payload, there is an optimum set of proportions at which the desired capability can be provided at least cost. Ideally, the ship selection would be made by defining overall system constraints (payload, speed, range, etc.) and by seeking that set of design parameters which minimizes total life cycle cost. In the present case, analysis was simplified in that for any given payload weight, hull volume operational speed and range capability, each choice of L/B and cushion density determines a maximum ship size. As a result, the choices of length-to-beam (L/B) ratio and "cushion density" [weight (lbs)/(cushion area)$(ft^2)^{3/2}$] which produce the least ship displacement for a given payload (or the maximum payload for a given displacement) are very nearly the optimum values for the system since the major cost components such as hull construction, machinery installation and fuel consumption are approximately minimized. In analyses of this kind, payload is determined as a function of L/B ratio and cushion density for a given powerplant, ship speed, and operational range. Pre-established design parameters such as the relationships of structural weight to ship displacement; specific fuel consumption to power level and propulsive efficiency to ship speed are used in the calculation. The proportional relationships of L/B ratio and cushion density are constrained to values demonstrated to be successful in moor tests and full scale craft.

For this study a range of L/B ratios from 3.5 to 7.55 were considered. The upper limit value of 7.55 was selected in that this value is presently considered to be close to the maximum value at which stability requirements, particularly in failure modes, can be satisfied. In addition, analysis has indicated that the improvement in operating economy above this value is, at best, extremely small. The cushion density of successful surface effect craft developed to date has ranged from 1.8 to 3.2 pounds per cubic foot and cushion densities within this region were selected for this study.

It should be noted that the acceptable values of L/B ratio and cushion density are directly related to craft proportions with the high values of the ranges identified above being applicable only to SES craft above 1000 tons displacement. Additionally it should be noted that overall system capability is not very sensitive to the exact choice of these variables and thus they may be adjusted if necessary to account for practical factors which may not be considered in the basic ship sizing process.

4.2 WEIGHT ESTIMATION

Payload weight estimates were derived from the lists of specific mission related equipments, manning and endurance requirements as specified in Section 3. Lightship weight items were derived from prior SES studies for ships of closely equivalent displacements and hull proportions and from manufacturers catalogue information. The weight estimates derived for the four design concepts are summarized in Tables 4.2-1 through 4.2-4.

Table 4.2-1. WHEC-SES Weight Estimate

SWBS	ITEM	LONG TONS
100	Hull Structure and Seals	522.0
200	Propulsion and Lift Systems	190.0
300	Electric Power Generation and Distribution System	42.0
400	Command and Surveillance System	58.0
500	Auxiliary Subsystems	73.0
600	Outfit and Furnishings	120.0
700	Combat System	30.0
	Estimated Lightship (without margin)	1035.0
	Design and Construction Margin (10%):	104.0
	Design Lightship	1139.0
F10	Personnel	42.4
F30	Stores	25.6
F50	Liquids and Gases	28.5
F23	Ordnance Delivery Systems	6.0
F21 } F29 }	Mission Related Expendables	38.5
F42	Helo Fuel	16.0
F42	Ships Fuel	804.0
	Full Load Displacement (FLD)	2100.0

Table 4.2-2. WMEC-SES Weight Estimate

SWBS	ITEM	LONG TONS
100	Hull Structure and Seals	285.0
200	Propulsion and Lift Systems	100.0
300	Electric Power Generation and Distribution System	30.0
400	Command and Surveillance System	50.0
500	Auxiliary Subsystems	55.0
600	Outfit and Furnishings	60.0
700	Combat System	0
	Estimated Lightship (without margin)	580.0
	Design and Construction Margin (10%):	58.0
	Design Lightship	638.0
F10	Personnel	21.6
F30	Stores	6.1
F50	Liquids and Gases	14.6
/	Mission Related Equipment (Payload)	17.6
F23	Ordnance Delivery Systems	5.0
F21 F29	Mission Related Expendables	20.0
F42	Helo Fuel	12.1
F42	Ships Fuel	300.0
	Full Load Displacement (FLD)	1035.0

Table 4.2-3. WLB-SES Weight Estimate

SWBS	ITEM	LONG TONS
100	Hull Structure and Seals	300.0
200	Propulsion and Lift Systems	85.0
300	Electric Power Generation and Distribution System	25.0
400	Command and Surveillance System	30.0
500	Auxiliary Subsystems	30.0
600	Outfit and Furnishings	30.0
700	Combat System	25.0
	Estimated Lightship (without margin)	525.0
	Design and Construction Margin (10%):	53.0
	Design Lightship	578.0
F10	Personnel	11.6
F30	Stores	2.0
F50	Liquids	5.0
/	Mission Related Equipment (Payload)	50.0
F23	Ordnance Delivery Systems	0
F42	Helo Fuel	0
F42	Ships Fuel	154.0
	Full Load Displacement (FLD)	800.6

Table 4.2-4. WPC-SES Weight Estimate

SWBS	ITEM	LONG TONS
100	Hull Structure and Seals	72.0
200	Propulsion and Lift Systems	35.0
300	Electric Power Generation and Distribution System	6.0
400	Command and Surveillance System	0.6
500	Auxiliary Subsystems	23.0
600	Outfit and Furnishings	19.0
700	Combat System	2.8
	Estimated Lightship (without margin)	158.4
	Design and Construction Margin (10%):	15.8
	Design Lightship	174.2
F10	Personnel	4.7
F30	Stores	3.0
F50	Liquids and Gases	3.0
/	Mission Related Equipment (Payload)	10.3
F23	Ordnance Delivery Systems	4.4
F42	Helo Fuel	9.4
F42	Ships Fuel	41.0
	Full Load Displacement (FLD)	250.0

4.3 SPACE ESTIMATION

Space requirements were derived from the space allocations currently provided in existing USCG ships of similar types; however, the lay-out process resulted in some differences. It was often desirable to: (1) provide an allowance for possible loss in deck area resulting from the subsequent preparation of detailed arrangements and (2) provide an allowance for increased habitability standards.

The results of this analysis are presented in Tables 4.3-1 through 4.3-4.

4.4 DESIGN DEVELOPMENT

The ship proportions and design characteristics provided through the process discussed in Paragraph 4.1 are summarized in Table 4.4.1.

Having chosen ship sizes and proportions appropriate to the selected applications, the design development addressed the analysis of performance characteristics and various subsystems and the development of drawings to illustrate the specific characteristics of hull geometry, internal space allocations and machinery installations. The analyses related to performance and subsystems are presented in Sections 5 and 6 respectively. The arrangement drawings and design details for each USCG - SES design concept are presented in the appendices.

Table 4.3-1. WHEC-SES - Deck Area and Hull Volume Allocations

SPACE DESCRIPTION		WHEC-SES		EXISTING CRAFT			
				378 FT WHEC			
		FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
BERTHING	CO (and Guest)	180	90	176	88		
	XO	140	140	121	121		
	EO	140	140	121	121		
	Officer (1 Person Stateroom)	100	100	88	88		
	Officer (2 Person Stateroom)	170	85	124	62		
	CPO	462	38.5	554	46.2		
	EM	3408	24	3328	23.4		
SANITARY	CO (and Guest)	85		68			
	XO	35		32			
	EO	35		32			
	Officer (1)	30		33			
	Officer (2)	30		38.5			
	CPO	126		81			
	EM	741		665			
MESS	CO (Cabin/Office)	336		340			
	Ward Room	707		587			
	CPO Mess CPO Lounge	382		375			
	EM Mess	868.1		870			
	EM Lounge	1150		1115			
COMMISSARY	CO Pantry	60		52			
	Officer Pantry	82		96			
	Galley	621		448			
	Scullery	112		90			
	Chill	106		175			
	Freeze	106		135			
	Dry Provisions	200		192			
	Ship Service	546		300			
	Barber Shop	110		60			
	PO	78		19			
	Ship Service Storeroom Supply Storeroom Small Stores ET Stores WR Stores	692		539			
	Sea Bag Storage	187		76			
	(Continued on next page)						

Table 4.3-1. WHEC-SES - Deck Area and Hull Volume Allocations (Cont'd.)

SPACE DESCRIPTION		WHEC-SES		EXISTING CRAFT			
				378 FT WHEC			
		FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
MED.	Medical Facility	286		240			
	TOTAL	12311		11170.5			
	Pilothouse	530		440			
	Chart Room	370		30			
	CIC	815		460			
	Communication Center	459		462			
	Radio Transmitter	220		-			
	Sonar Room	100		85			
	Fire Control Room	238		272			
	MK92 Equipment Room	140		-			
	TTY and Cripto	157		173			
	Air NAV and ECM	122		68			
	TACTAS Control Room	108		-			
	TACTAS Equipment Room	264		-			
	Radar, IFF & CIC Equipment Room	1070		654			
	IC and Gyro	342		313			
	Sonar Equipment Room	204		192			
	CIWS Control Room	108		-			
	Helo Control Station	40		-			
	Central Control Station	558		280			
	TOTAL	5845		3429			
	511-38 Magazine	-		216			
	76mm Magazine	338		-			
	20-40mm Magazine	104		168			
	50 Cal. Magazine	80		40			
	Small Arms Magazine Armory	75		32			
	CIWS Magazine	189		-			
	Helo Hangar	1152		-			
	Aviation Space (Off., Store, Shops, etc.)	2196		40			
	Torpedo Storage	-		95			
	TOTAL	4134		591			
	Unassigned	2500					

Table 4.3-1. WHEC-SES - Deck Area and Hull Volume Allocations (Cont'd.)

SPACE DESCRIPTION	WHEC-SES		EXISTING CRAFT			
			378 FT WHEC			
	FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN

OTHER EQUIPMENT:

Water
Required = 28.5 Tons
Available = 45.6 Tons

Fuel
Required* = 804 + 16 = 820 Tons
Available
Tanks (1 & 2) = 74 x .95 x .98 = 68.9 Tons
Tanks (3 & 4) = 79 x .95 x .98 = 73.5 Tons
Tanks (5 & 6) = 45 x .95 x .98 = 42.2 Tons
Tanks (7 - 12) = 202 x .95 x .98 = 188 Tons
Tanks (13 - 16) = 548 x .95 x .98= 510.2 Tons

TOTAL 882.8 Tons

* The values given are ship and helo fuel estimates (Figure 4.2-1.)

Table 4.3-2. WMEC-SES - Deck Area and Hull Volume Allocations

SPACE DESCRIPTION		WMEC-SES		EXISTING CRAFT			
				210 FT WMEC		270 FT WMEC	
		FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
BERTHING	CO Cabin	269	269	270	270	180	180
	XO	148	148	99	99	105	105
	EO	100	100	91	91	105	105
	Officer	1050	116.7	597	66.3	612	68
	CPO	524	58.2	276	30.7	379	42.1
	EM	1200	17.4	1566	22.7	1730	25.1
SANITARY	CO	30		32		28	
	XO	30		28		24	
	EO	30		28		24	
	Officer	150		191		74	
	CPO	95		70		124	
	EM	800		368		454	
MESS	Wardroom	660		256		338	
	CPO Mess	170		144		135	
	CPO Lounge	192					
	EM Mess	788		501		565	
	EM Lounge	456				394	
COMMISSARY	Officer Pantry	110		75		-	
	Galley	478		260		332	
	Scullery	77		70		90	
	Chill	115		48			
	Freeze	100		46		204	
	Dry Provisions	225		96			
	Ship Service	160		20		75	
	Laundry	207		198		135	
	Barber Shop	84		-		-	
	Sea Bags	390		-		183	
MED.	Medical Facility	170		40		62	
	TOTAL	8808		5370		6352	

Table 4.3-2. WMEC-SES - Deck Area and Hull Volume Allocations (Cont'd.)

SPACE DESCRIPTION	WMEC-SES		EXISTING CRAFT			
			210 FT WMEC		270 FT WMEC	
	FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
Pilothouse	371		260		312	
Chart Room	112		9		21	
CIC	712		168		-	
Sensor Room and Command Support Center	813		-		1032	
Communication Center	-		-		624	
Radio Room	-		168		-	
IC and Gyro	231		180		110 (Gyro)	
Code Room	-		72			
Flight Control Station	25		-		13	
TOTAL	2264		857		2112	
Magazines	475		100		397	
TACTAS Equipment Room	228		-		100	
TACTAS Control Room	84		-		-	
Helo Hangar	1372		-		380	
Aviation Stores, Off, etc	1107		-		377	
Armory	64		14		35	
TOTAL	3330		114		1289	
Unassigned	1161					

OTHER EQUIPMENT:

Water

Required =	14.6 Tons
Available (Tanks 1 & 2) = 24 x .95 x .98 =	22.4 Tons

Fuel *

Required = 300 + 12.1 =	312.1 Tons
Available	
Tanks (1 & 2) = 14.6 x .95 x .98 =	13.6 Tons
Tanks (3 & 4) = 30.2 x .95 x .98 =	28.1 Tons
Tanks (5, 6, 7, 8, 9, 10, 11 & 12) = 165.6 x .95 x .98 =	154.2 Tons
Tanks (11 & 12) = 39 x .95 x .98 =	36.3 Tons
Tanks (13, 14, 15, 16, 17, 18,	36.3 Tons
19 & 20) = 226.8 x .95 x .98 =	211.2 Tons
* The values given are ship and helo fuel estimates (Figure 4.2-2.)	479.7 Tons

Table 4.3-3. WLB-SES - Deck Area and Hull Volume Allocations

SPACE DESCRIPTION		WLB-SES		EXISTING CRAFT			
				180 FT WLB			
		FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
BERTHING	CO Cabin	191	191	167	167		
	Officer	256	85	341	113.7		
	CPO	210	105	190	95		
	EM	946	22.5	683	16.3		
SANITARY	CO	39		24			
	Officer	48		49			
	CPO	60		39			
	EM	272		90			
MESS	Ward Room	198		223			
	CPO Mess and Lounge	152		134			
	EM Mess	264		259			
	EM Lounge	229		-			
COMMISSARY	Officer Pantry	36		49			
	Galley	275		132			
	Scullery	52		46			
	Cold Storage	139		124			
	Dry Food	144		140			
	Laundry	132		63			
	Barber	55		-			
	Ship Service	110		33			
	TOTAL	3808		2786			

Table 4.3-3. WLB-SES - Deck Area and Hull Volume Allocations (Cont'd)

SPACE DESCRIPTION	WLB-SES		EXISTING CRAFT			
			180 FT WLB			
	FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
Pilothouse	318		263			
C^3	710		158			
Central Control Sta.	220		105			
Ship Offices	276		174			
General Stores	270		-			
Spare Parts	270		74			
Hawser and Refc. Equip.	263		47			
BSN Lkr.	230		391			
Hose Rack	105		54			
Cargo Hold	616		439			
EM Shop	-		41			
DC Shop	-		141			
DC Stores Lkr.	-		30			
ET Stores	-		30			
Unassigned	2734					
TOTAL	6012		1947			

OTHER EQUIPMENT:

Water
Required 58 Tons
Available (Tanks 1 & 2) = 67 x .95 x .98 = 62.4 Tons

Fuel
Required = 154 Tons
Available (Tanks 3, 4, 5, 6) = 210 x .95 x .98 = 196 Tons

Cargo Hold
Required = 4300 Ft^3
Available = 5259 Ft^3

Table 4.3-4. WPC-SES - Deck Area and Hull Volume Allocations

	SPACE DESCRIPTION	WPC-SES		EXISTING CRAFT			
				95 FT WPB			
		FT²	FT²/MAN	FT²	FT²/MAN	FT²	FT²/MAN
BERTHING	CO	105	105	69	69		
	Officer	81	81	-	-		
	CPO	120	40	42	14		
	EM	670	35.3	234	12.3		
SANITARY	CO	17.5					
	Officer	17.5		20.5			
	CPO	225					
	EM	114		70.5			
MESS	Ward Room	80					
	CPO Mess	80		132			
	EM Mess	238					
	EM Lounge	165		-			
COMMISSARY	Galley	122					
	Scullery	26					
	Chill	9		77			
	Freeze	9					
	Dry Food	12					
	Laundry	50		-			
	TOTAL	2141		645			

Table 4.3-4. WPC-SES - Deck Area and Hull Volume Allocations (Cont'd.)

SPACE DESCRIPTION	WPC-SES		EXISTING CRAFT			
			95 FT WPB			
	FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
Pilothouse	201		68			
Command, Control and Communication	332		64			
Magazine	56		-			
Armory	28		-			
Central Control Station	34		-			
BSN Lkr.	203		74			
CHT System	53		42			
Ship Office	54		-			
Storeroom	195		39			
Mach. and Auxiliary	692		360			
Third Generator	185		66			
TOTAL	2033		713			
Unassigned	288.6					

OTHER EQUIPMENT:

Water

Required 3 Tons

Available = 5.2 x .95 x .98 = 5.1 Tons

Fuel

Required* = 41. + 9.4 = 50.4 Tons

Available

Tank (1 & 2) = 35.3 x .95 x .98 = 32.9 Tons

Tank (3 & 4) = 19.1 x .95 x .98 = 17.8 Tons

Tank (5, 6, 7 & 8) = 70.6 x .95 x .98 = 65.7 Tons

TOTAL 116.4 Tons

*The values given are ship and helo fuel estimates (Table 4.2-4.)

Table 4.4-1. Ship Concept Selection Summary

CRAFT	V	FLD	LOA	BOA	B_c	L_c	H_c	L_c/B_c
WHEC	30 (1)	2100	300.0	68.0	39.0	269.0	22.0	6.72
WMEC	35 (2)	1035	280.0	55.0	33.3	252.0	20.0	7.55
WLB	20 (1)	800.6	220.0	50.0	31.0	196.0	16.0	6.32
WPC	25 (3)	250	129.0	40.0	31.0	113.0	9.0	3.65

(1) Calm Water

(2) 35 Knot Dash Capability (Calm Water)

(3) Sea State 3

5 / PERFORMANCE ANALYSIS

Performance analysis was developed sufficiently to provide a high measure of confidence for each design concept in the areas of speed and power relationships, ride quality, and stability.

5.1 DRAG SPEED AND RANGE

The drag speed and range characteristics were derived from the large body of data developed through extensive model testing of SES craft conducted at NSRDC and other facilities. A typical test program conducted in this area is presented in References 5-1 and 5-2. The performance predictions for each of the ship concepts addressed within this study were derived by the methods discussed in Reference 5-3.

The results of the speed and range analysis performed for each of the four design concepts are summarized in Table 5.1-1. The performance curves related to each design are included in the design descriptions presented in Appendices I through IV.

5.2 SHIP STABILITY AND MANEUVERABILITY

This section presents the analysis of the ship stability and maneuverability characteristics for the ship design concepts.

Table 5.1-1. Ship Performance Summary

SHIP CONCEPT	FULL LOAD DISPLACEMENT (LT)	FUEL WT (LT) [1]	PROPULSION H.P.	LIFT H.P.	SPEED AT FLD (KNOTS)				RANGE (N. M.)				AV. SPEED (KN)	
					HULLBORNE		CUSHIONBORNE		HULLBORNE		CUSHIONBORNE		CUSHIONBORNE	
					SS 0	SS 3	SS 0	SS 3	SS 0	SS 3	SS 0	SS 3	SS 0	SS 3
WHEC-SES	2100	804	34,000	16,000	20	19	32	29	-	-	4,900	4,500	43	40
WMEC-SES	1035	300	14,000	6,100	20	19	35	30	-	-	3,700	3,250	39	34
WLB-SES	800.6	154	8,500	4,000	-	-	26	24	-	-	2,140	1,900	28	26
WPC-SES	250	41	5,400	1,800	-	12[2]	30	25	-	-	-	1350[2]	-	-

NOTES:

1. With 10 percent reserve fuel margin.
2. Range and Speed are for SS2 for the WPC-SES

5.2.1 SCOPE -- Since this study addresses design development at the concept feasibility level of detail, the following analyses investigate a range of possible hull geometry configuations which may be employed should all concepts or any one concept be selected for more detailed development. Analyses conducted in this area required the expenditure of a significant portion of the resources available for the study. As a consequence the investigations were constrained to the investigation of one SES selected to be representative of the two larger design concepts (WHEC and WMEC). Additionally, in that stability characteristics generally demonstrate a negative (degrading) trend with increasing speed, the speed related analyses were accomplished assuming a ship speed equivalent to the highest speed attainable by the WHEC design in the "burned-out" condition. (i.e. 52.7 knots). The "burned-out" condition is for no fuel remaining at a constant power setting.

5.2.2 ROLL, DRIFT AND DIRECTIONAL STABILITY

5.2.2.1 Stability Criteria -- The stability criteria identified for all USCG SES designs are:

a. Dynamically stable under all operating conditions.
b. Controllable under transient conditions and failure modes.
c. Positive (i.e., stabilizing) restoring moments at all attainable attitudes.

5.2.2.2 Sources of Data -- Stability data were taken from the results of test series conducted at DTNSRDC and reported in Reference 5-2. In the reference work, sidewall deadrise angles of 28.5, 45, and 45/28.5 degrees were tested and forces and moments measured under steady-state conditions for various craft attitudes and speeds. Dimensionless force and moment coefficients were derived from test data for a model having a cushion length/beam ratio of 7.15. Additionally, regression analysis of the test data has been performed to ascertain the influence of ship design and operating properties on stability. This work is documented in Reference 5-4.

Sign conventions are as follows:

a. X, the roll axis, is positive forward.
b. Y, the pitch axis, is positive to starboard.
c. Z, the yaw axis, is positive to downward.
d. Angles are taken to be positive in accordance with the righthand rule.
e. Drift angle is positive when the ship's X-axis is clockwise from the velocity vector.

5.2.2.3 Static Roll Stability -- The static roll stability on-cushion is assessed by plots of roll moment under various conditions. The following discussion presents the results of a model test for a 1500 LT ship. The results are generally applicable to any geosym.

For the 28.5-degree deadrise hull, Figure 5.2-1 shows roll moment coefficients versus drift angle for various roll angles and a speed of 52.7 knots. It can be seen that the curves cross at drift angles of 5 to 7 degrees. The same data is crossplotted in Figure 5.2-2 as roll moment versus roll angle. The slope of the curve, i.e., the roll stiffness vanishes at large drift angles, indicating a roll instability at such conditions due to "swamping" of the outboard chine. Note that in practical design applications fins would be installed to preclude the occurrence of the large drift angles created in the model test.

The corresponding plots for the 45-degree deadrise hull are given in Figures 5.2-3 and 5.2-4. For this configuration, the roll stiffness is lower, but is insensitive to drift angle since "swamping" of the outboard chine does not occur at any drift angle.

The double-deadrise sidehull investigated has a 45-degree deadrise from the keel up to the 4.5 feet waterline. Above this waterline the sidehull flares at 28.5 degrees. The chine is at the same waterline as for the 45-degree configuration discussed above. As shown in Figure 5.2-5 the role

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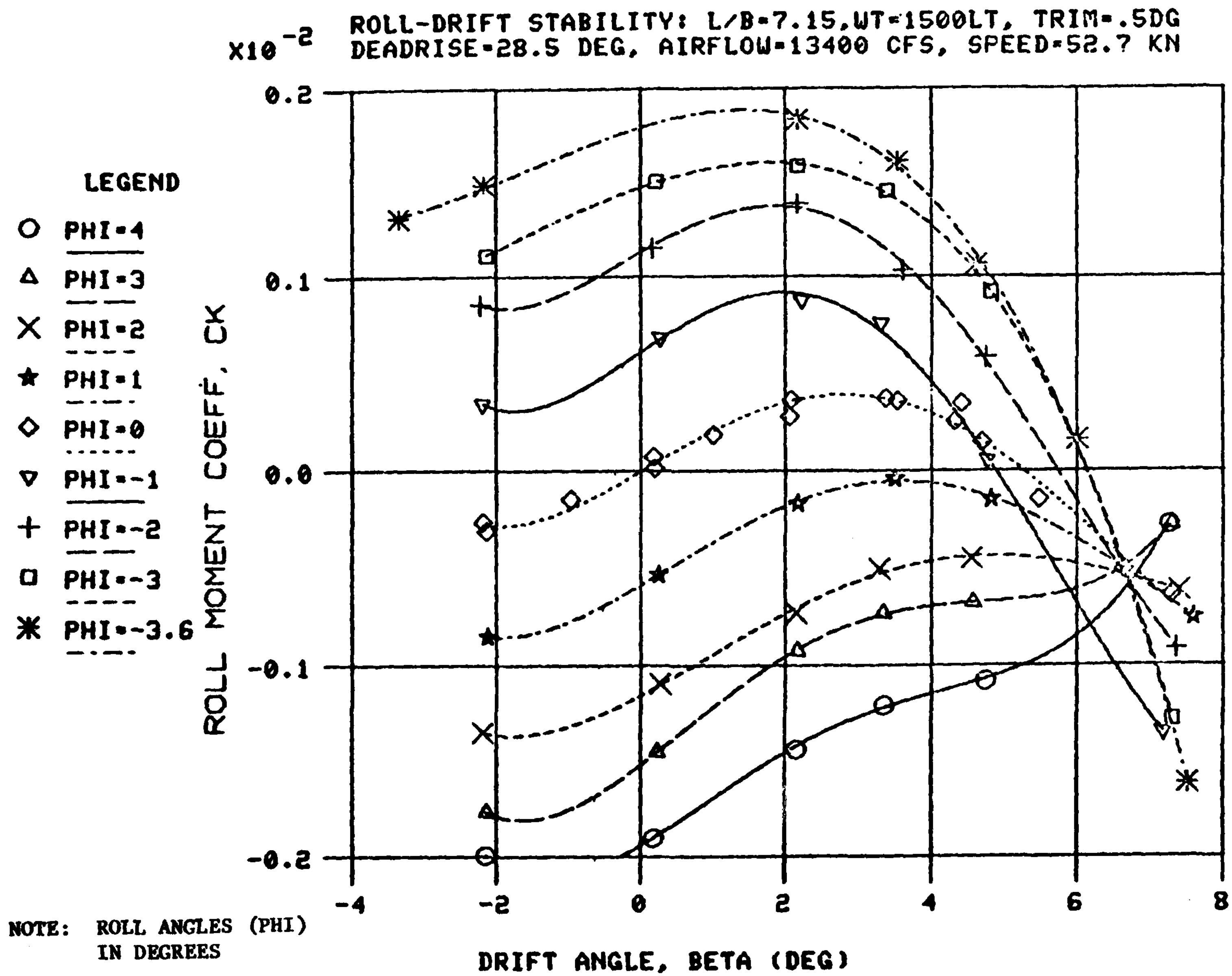
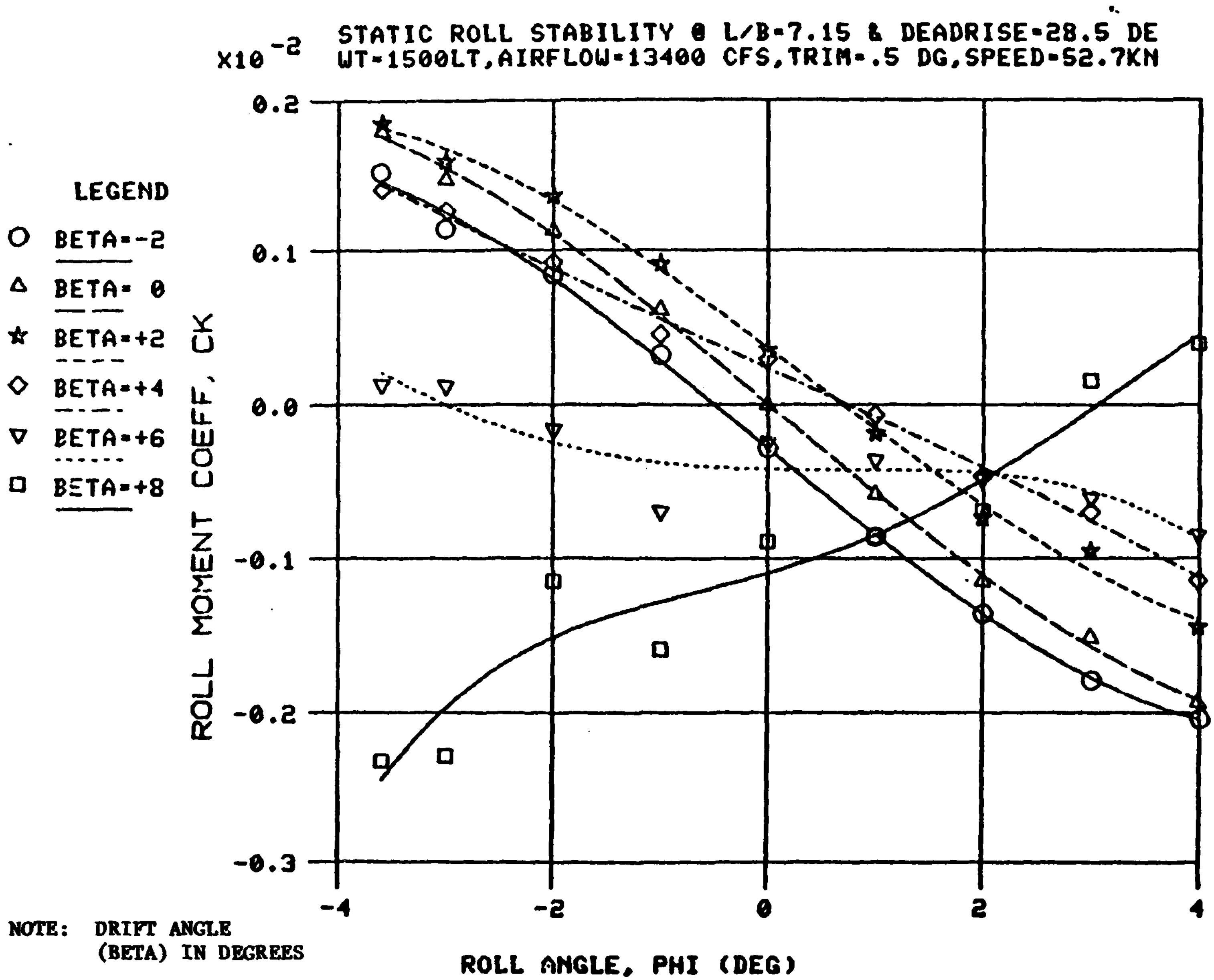


NOTE: ROLL ANGLES (PHI) IN DEGREES

Figure 5.2-1. Roll Moment Coefficient vs Drift Angle, 28.5 Degrees Deadrise (Parameterized on Roll Angle Phi)



NOTE: DRIFT ANGLE
(BETA) IN DEGREES

Figure 5.2-2. Roll Moment vs Roll Angle, 28.5 Degrees Deadrise
(Parameterized on Drift Angle Beta)

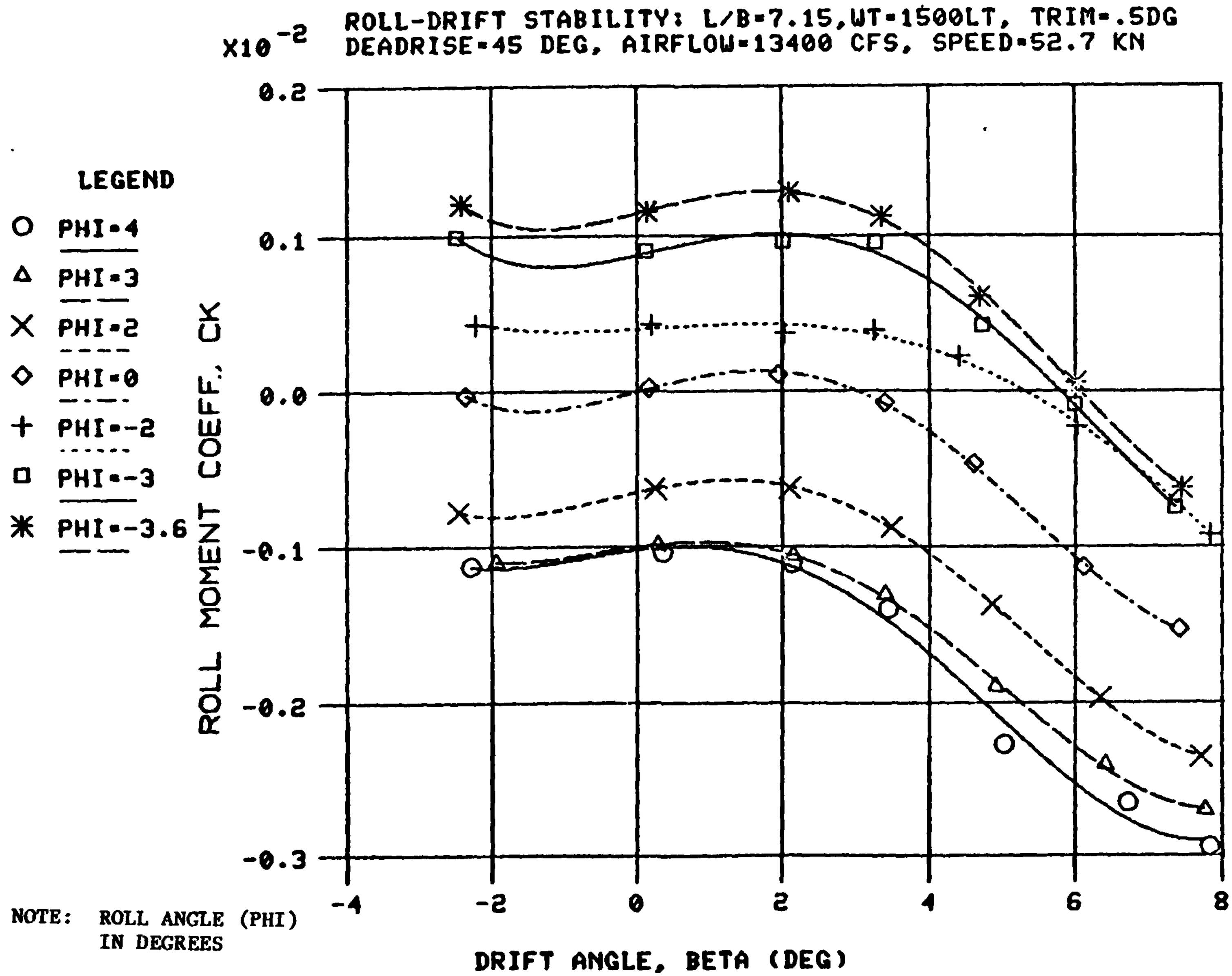


Figure 5.2-3. Roll Moment Coefficient vs Drift Angle, 45 Degree Deadrise (Parameterized on Roll Angle Phi)

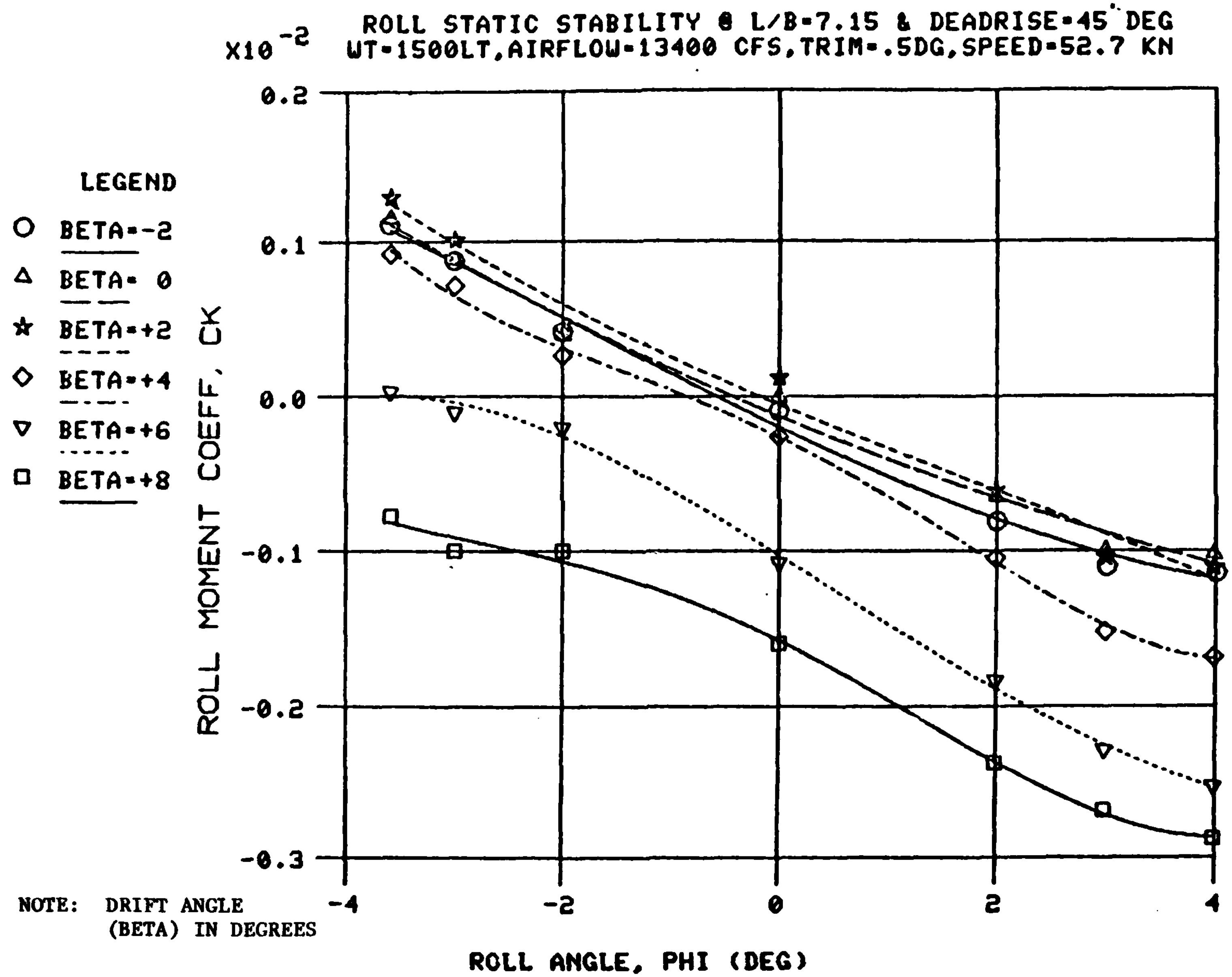


Figure 5.2-4. Roll Moment vs Roll Angle, 45 Degrees Deadrise
(Parameterized on Drift Angle Beta)

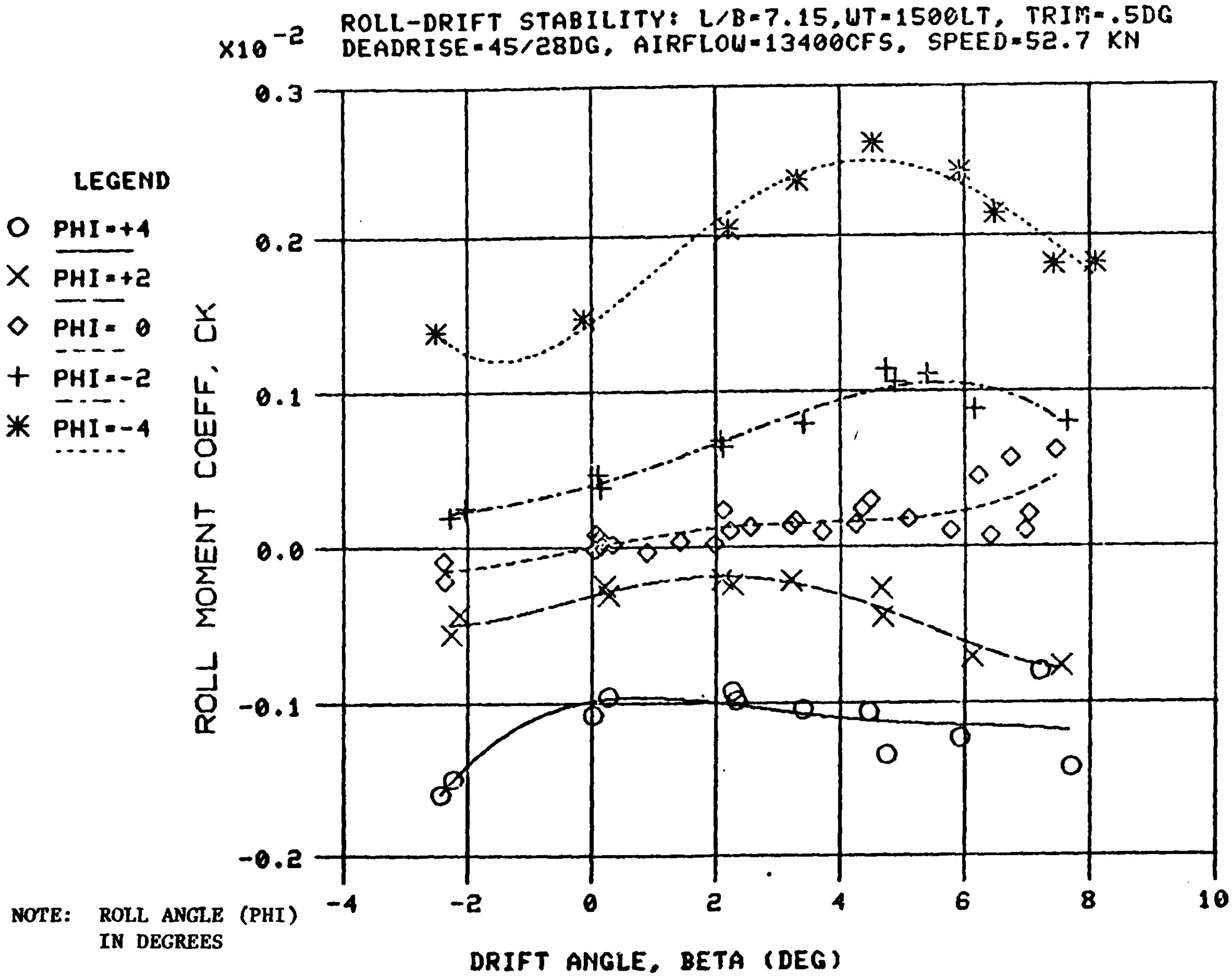


Figure 5.2-5. Roll Moment Coefficient vs Drift Angle, 45/28.5 Degrees Deadrise (Parameterized on Roll Angle Phi)

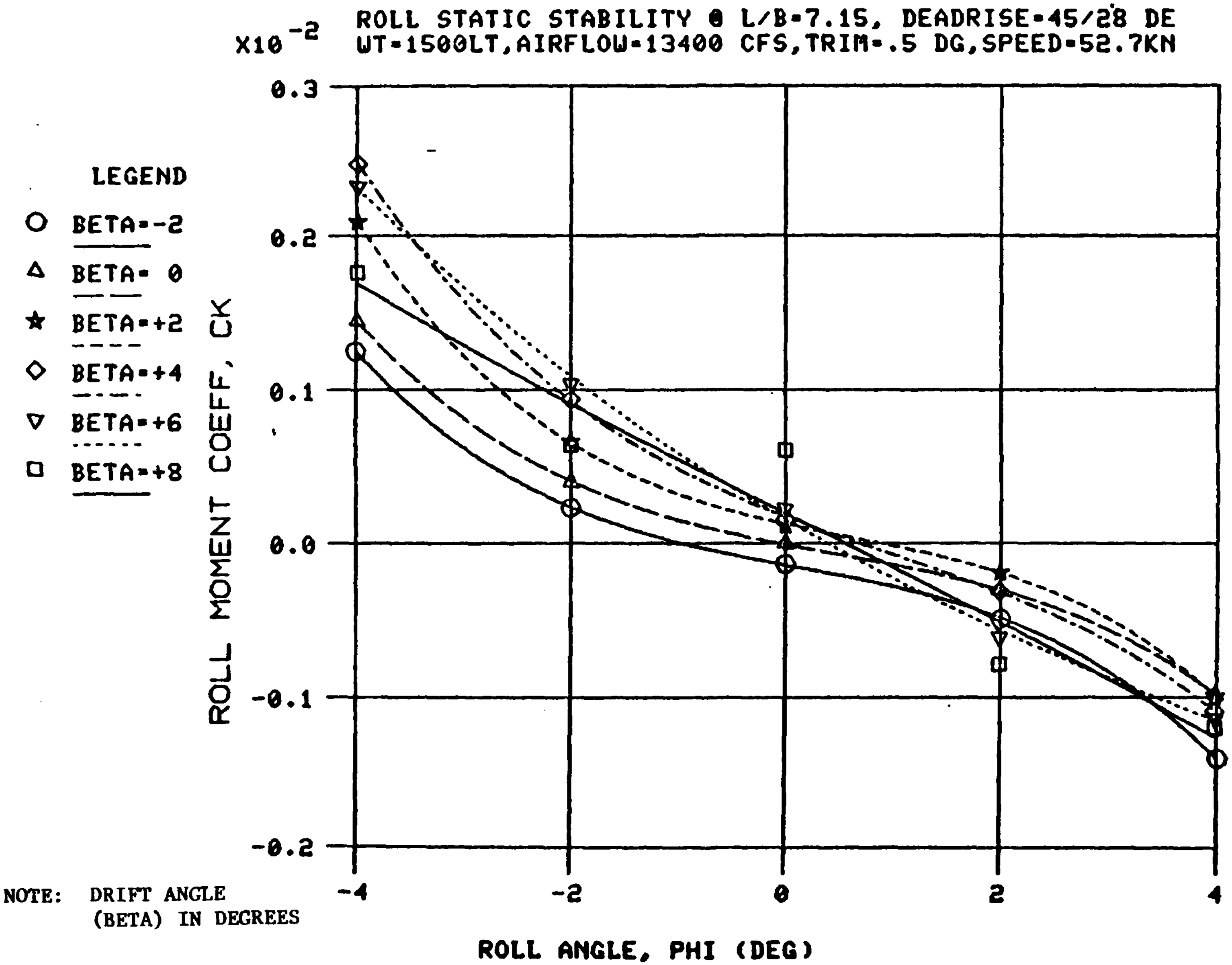
stability at small drift angles resembles that of the 45-degree case, while at large drift angles, it is more stable than either the 45 or 28.5-degree configurations. Figure 5.2-6 shows the roll moment coefficient versus the angle to be stable. In particular, it does not exhibit the static roll instability of the 28.5-degree deadrise hull.

Figure 5.2-7 illustrates clearly the effect of hull deadrise on the roll drift stability at zero roll angle. The data shown in Figure 5.2-7 do not include the influence of rudder forces which contribute to the "roll in" (positive roll angle) moment.

5.2.2.4 Yaw Stability -- Yaw stability was investigated relative to the requirement for the installation of fins for the purposes of yaw stabilization.

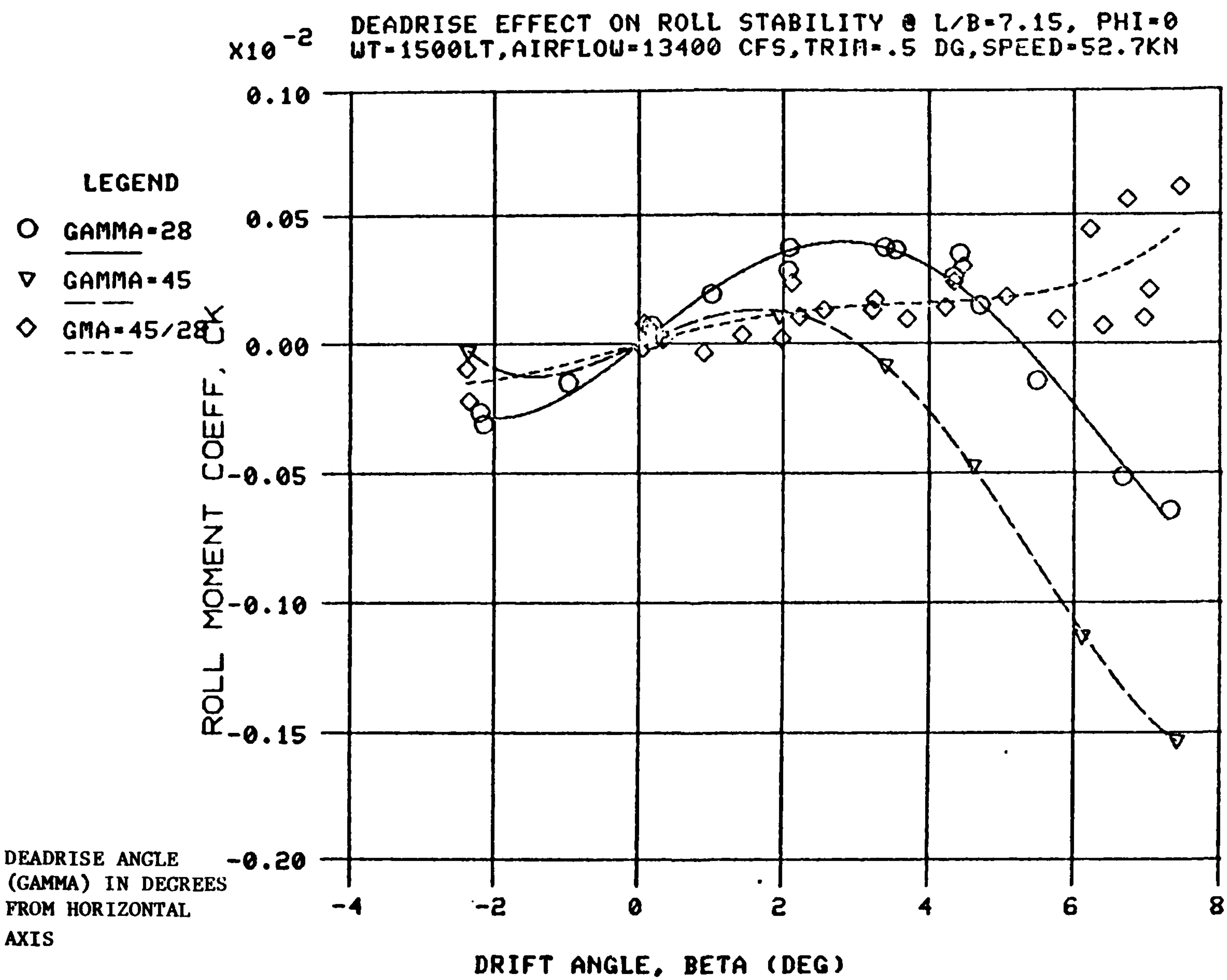
The results of this investigation are shown in Figure 5-8 which demonstrates that fins or fin and rudder combinations are required to ensure a satisfactory measure of yaw stability (i.e., "weathercock" characteristics). Figure 5.2-8 also shows the effect of flow breakdown at a drift angle exceeding 6 degrees. This phenomenon is not likely to occur with a fixed skeg installation, but may occur with a spade rudder configuration at high angles of deflection. Therefore fin and rudder combination might be considered for all USCG SES designs with the size and geometry developed through model tests at later stages of development.

5.2.2.5 Steady Turns -- Estimation of turning characteristics requires quantitative evaluation of yaw rate derivatives and static forces. The viscous damping of the ship contributes significantly to the performance in turning maneuvers. In the absence of direct experimental data for the design in question, two approaches were taken to estimate the yaw damping. Reference 5-5 gives experimental values of dimensional damping coefficients for sway, roll, and yaw for an SES model with a cushion L/B Ratio of 5. Scaling these coefficients to ship dimensions provided the first method of estimating the damping coefficients for analysis of steady turns.



NOTE: DRIFT ANGLE (BETA) IN DEGREES

Figure 5.2-6. Roll Moment vs Roll Angle, 45/28.5 Degrees Deadrise (Parameterized on Drift Angle Beta)



NOTE: DEADRISE ANGLE (GAMMA) IN DEGREES FROM HORIZONTAL AXIS

Figure 5.2-7. Effect of Deadrise Angle on Roll-Drift Stability at Zero Roll Angle (Parameterized on Deadrise Angle Gama)

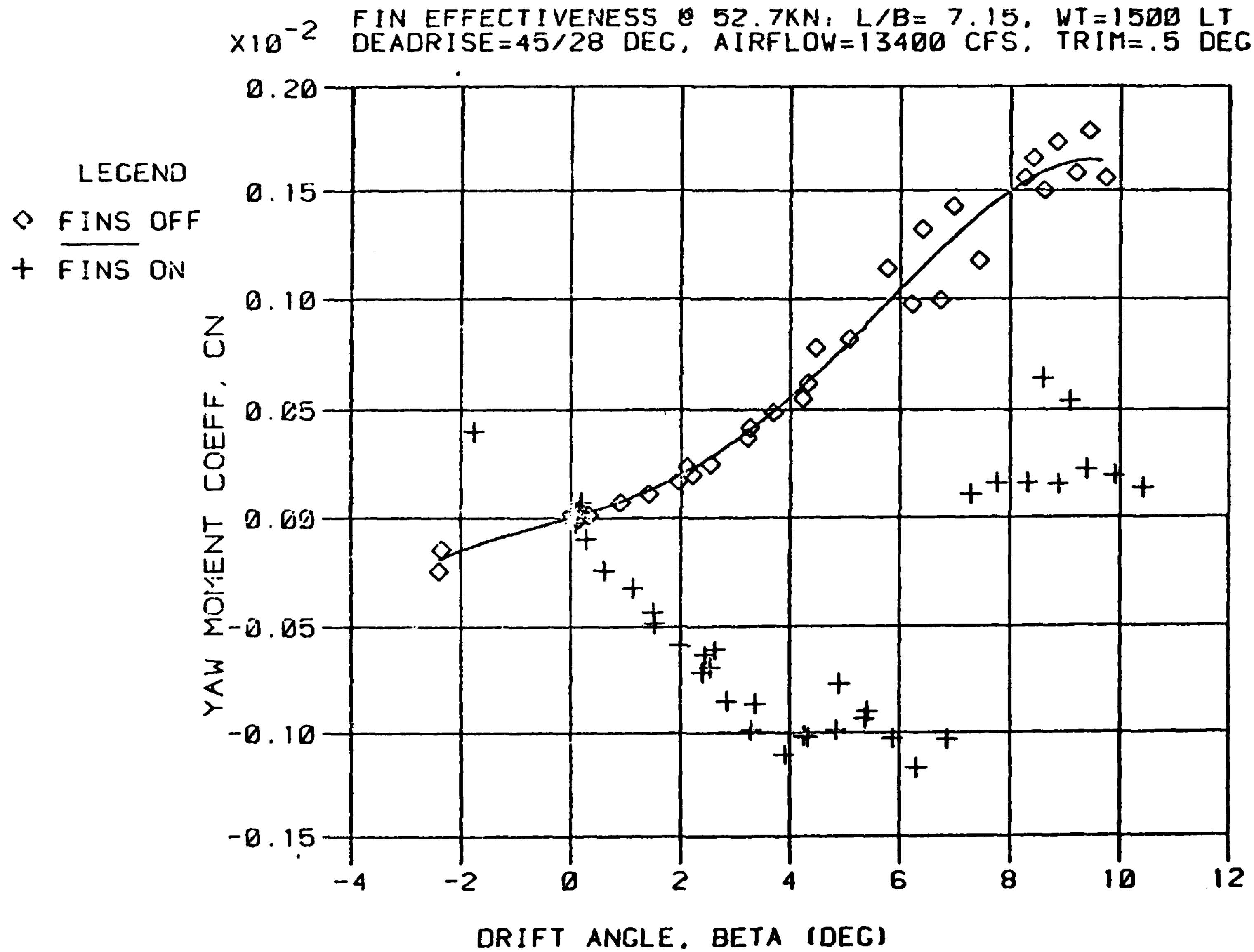


Figure 5.2-8. Yaw Moment Coefficient vs Drift Angle, With and Without Fins, 45/28.5 Degrees Deadrise

The second method involved measuring yaw moments on the NSRDC test model during a continuous yaw sweep at a speed of 22 feet per second (Reference 5-4). For each of 8-12 measurements taken during the test run, the difference between the dynamic yaw moment and the steady-state yaw moment provided an estimate of the moment due to yaw rate and was ascribed to yaw damping, Nr. These results form a somewhat consistent data set. The mean value of Nr was about 1 - 1/2 times that obtained by the first method but the disparity was ascribed to the fact that the NSDRC test model was immersed more than twice as much as the model reported by Reference 5-5.

A simulation of rudder-induced turns, using the estimated values of damping, for a 1500 long ton SES with 45/28.5 degree deadrise is shown in Figure 5.2-9. The turning rates shown in Figure 5.2-9 produces a lateral acceleration of approximately 0.1g and are therefore about the maximum values acceptable for practical design considerations. Figure 5.2-10 shows the pronounced effect of center of gravity height on roll angle. It is highly desirable for the craft to "roll-in" during high speed turns. For this characteristic to be provided the height of the center of gravity must be less than the point of intersection of the resultant of the side hull induced transverse hydrodynamic force and the longitudinal center plane of the craft.

5.2.2.6. Pitch Stability -- Pitch stability is not a matter of primary concern in SES designs which incorporate relatively high displacement ratio sidehulls and therefore no analysis was accomplished in this area.

5.2.2.7 Transverse Stability - Intact Condition -- The transverse stability for high L/B SES was investigated in the intact condition relative to the following considerations:

a. Influence of beam wind velocity combined with rolling.
b. Influence of vertical center of gravity (KG).

The analysis was concentrated in two principal operating modes, namely, off-cushion displacement mode and on-cushion hover mode. The criteria of evaluation are as set forth in Reference 5-6.

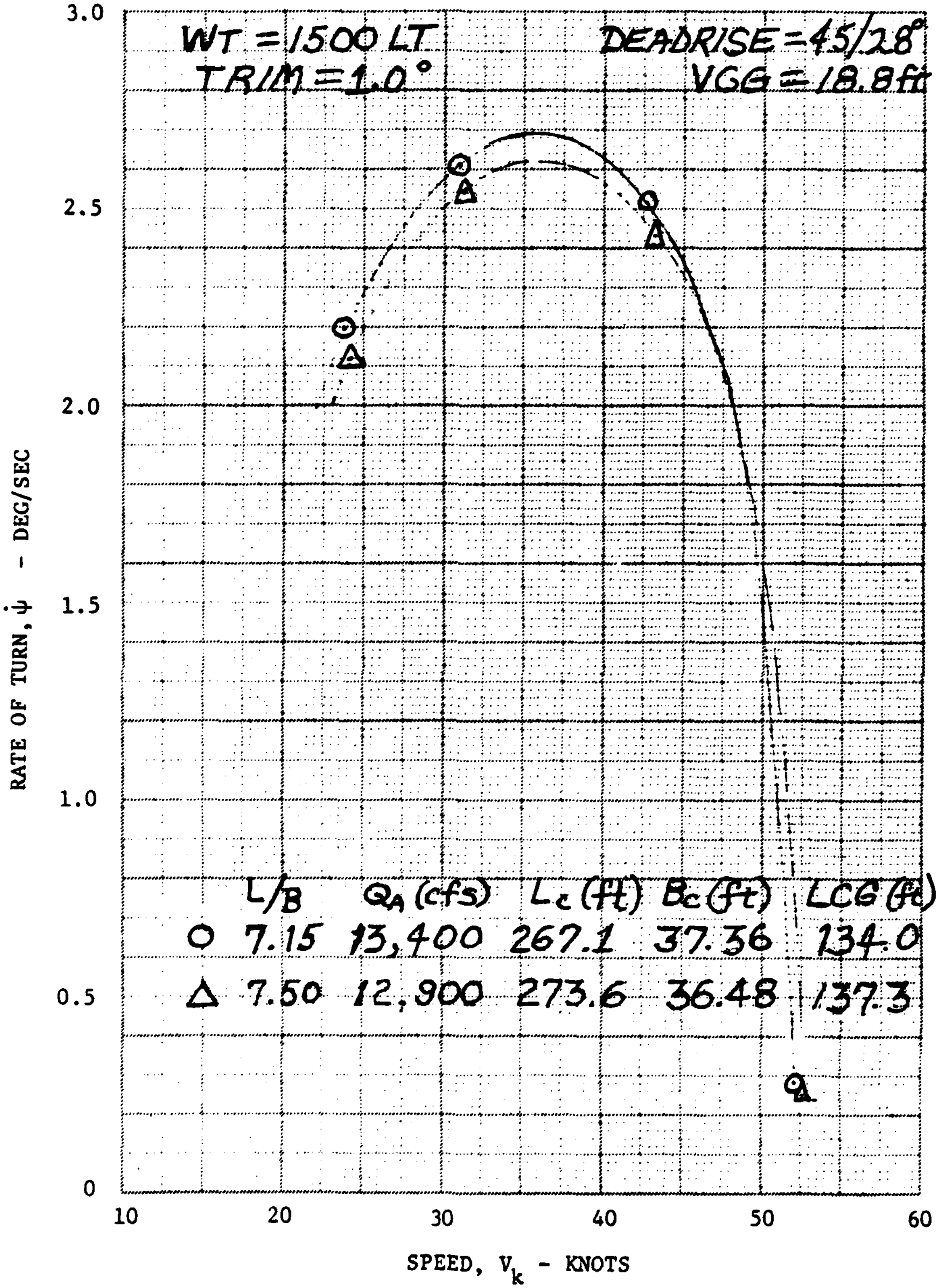


Figure 5.2-9. Rudder Induced Turn Performance

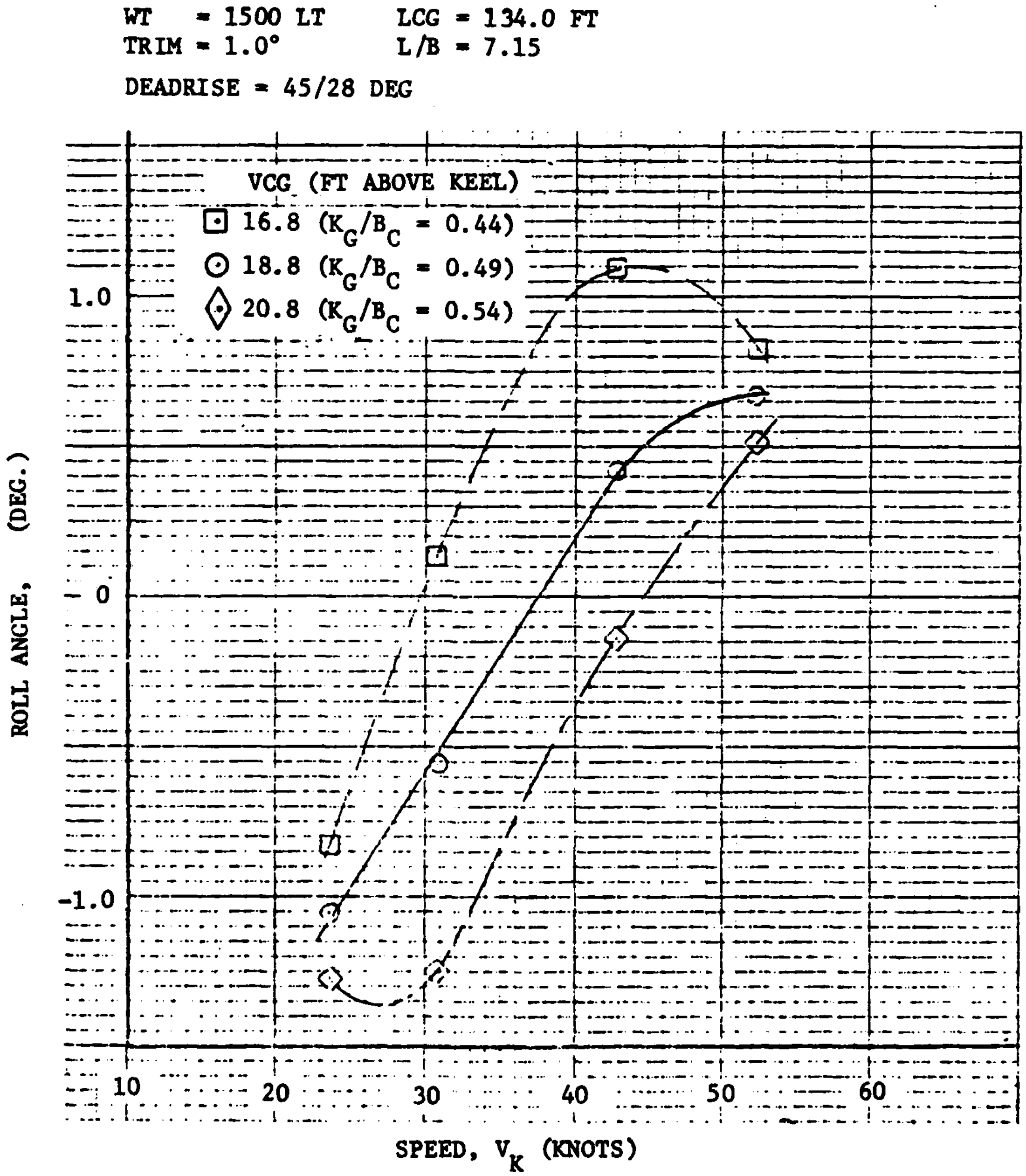


Figure 5.2-10. Effect of CG Height on Roll Angle in Turns

Parametric results show that in the hullborne displacement mode, with a wind velocity of 100 knots, the maximum permissible KG is 23.0 ft., as shown in Figure 5.3-11.

The envelopes of KG and beam wind velocity under which the criteria are satisfied are shown in Figure 5.2-12. It should be noted that the stability in the on-cushion "hover" mode was assessed without consideration of cushion venting as a result of rolling and assuming the craft to be stationary (i.e., without forward motion) and therefore without the benefit of the hydrodynamic righting moment which is produced by the sidehull when the craft is underway. The result of the detailed analysis for four selected points of the envelopes are presented in Figures 5.2-13 through 5.2-16.

5.3 SHIP MOTIONS AND RIDE QUALITY

The speed of conventional high performance ships in heavy seas is often limited more by the crew's unwillingness to risk the physical and physiological consequences of violent heave and pitch motion than by installed propulsive power. The physical consequences usually involve structural integrity of the ship or swamping, concerns of structural design and seakeeping. Physical confort aside, the physiological consequences of major concern is the impact on crew performance due either to motion sickness, reduction in physical task proficiency which is a direct result of vertical motion, or fatigue reduced proficiency resulting from long exposure to such motion. These aspects are the province of ride quality.

In most ships, the vertical motion is a direct function of speed and sea state above which little can be done. The SES, however, rides on a cushion of air which lifts the hull above the waves sufficiently to provide an acceptable crew environment under most sea conditions. The air cushion also offers a means for active ride control to further minimize motions in higher sea states.

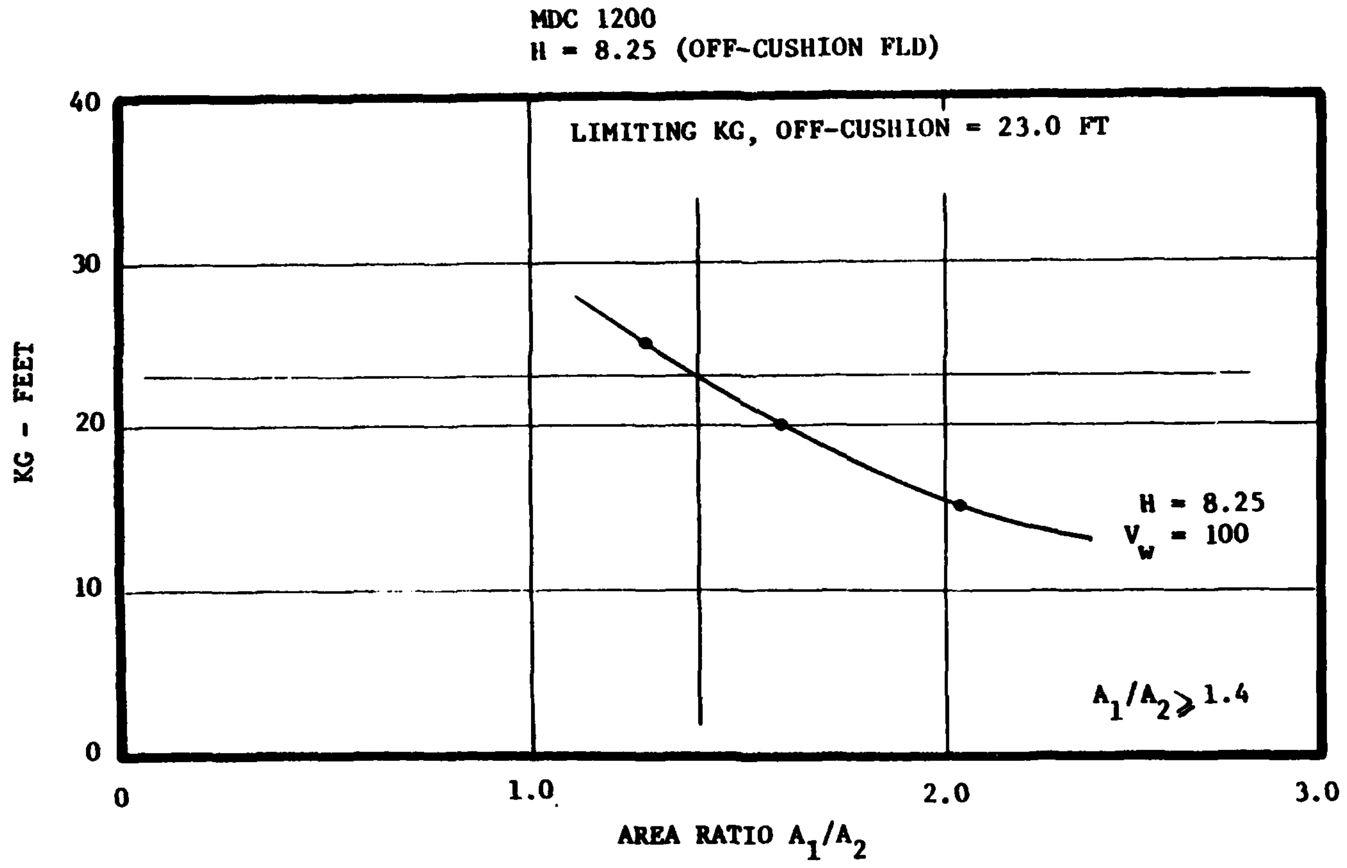


Figure 5.2-11. Limiting KG for Displacement Mode with 100 Knots Beam Wind

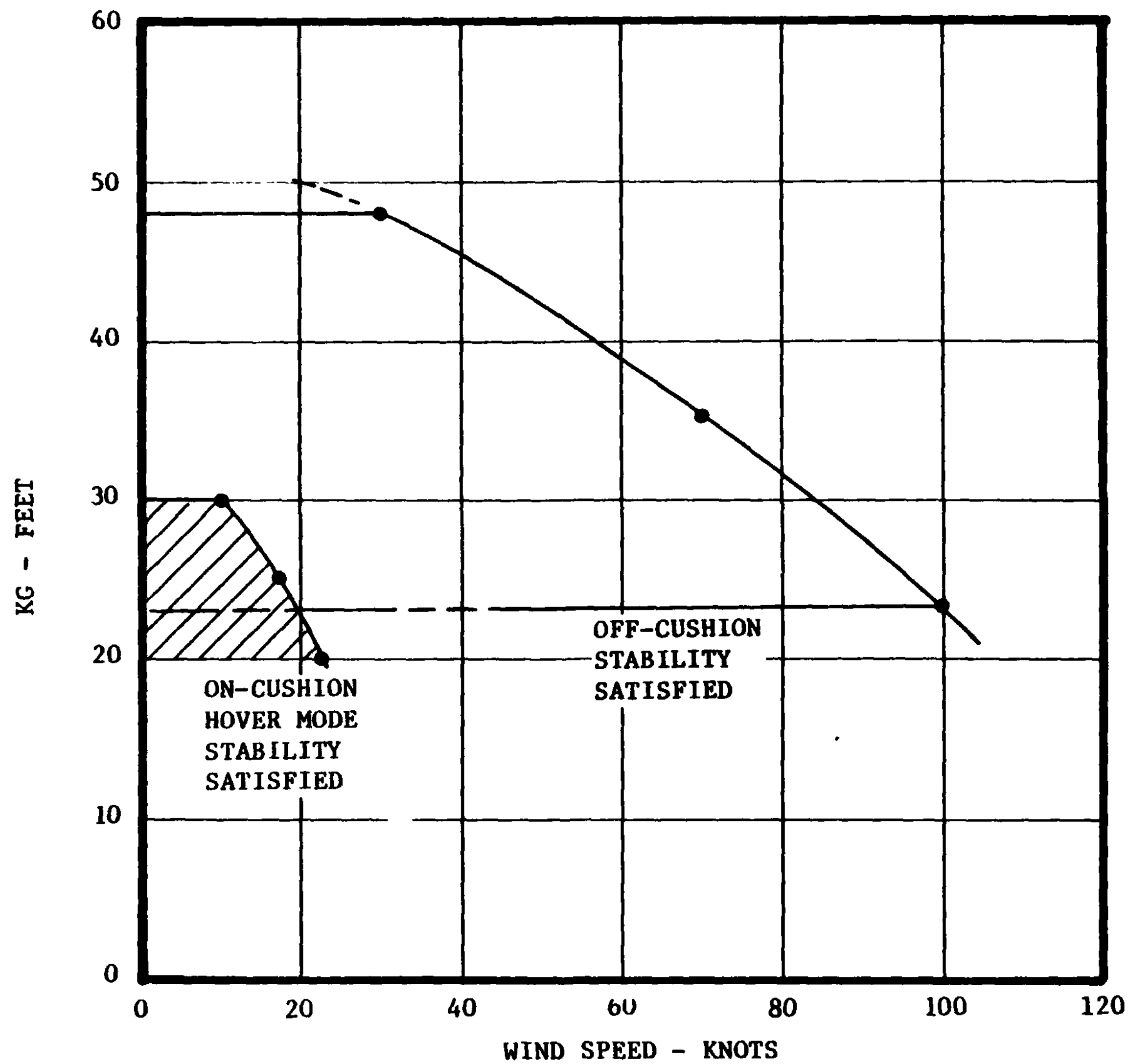


Figure 5.2-12. Envelope of KG and Wind Speed to Meet $A_1/A_2 \geq 1.4$

INTACT STABILITY

UPRIGHT HYDROSTATIC CHARACTERISTICS

SEA WATER DISPLACEMENT	=	1200.00 TONS	LONGITUDINAL CG (LCG)	=	167.97 FT AFT FP
LONGITUDINAL CB (LCB)	=	167.57 FT AFT FP	LONGITUDINAL CF (LCF)	=	166.34 FT AFT FP
VERTICAL CG (KG)	=	23.00 FT ABV RRWL	VERTICAL CB (KB)	=	5.31 FT ABV RRWL
MAXIMUM FREE-SURFACE	=	2000.00 TON-FT	VERTICAL C.G. (KG)	=	24.67 FT ABV RRWL
TRANSV. METACENTER (KMT)	=	105.47 FT ABV RRWL	LONG. METACENTER (KML)	=	1300.09 FT ABV RRWL
TRANSVERSE CB (TCB)	=	0.00 FT FRM RRVL	MOMENT TO ALTER TRIM (MTI)	=	415.11 TON-FT/INCH
TRIM (+VE : AFTWARD)	=	0.00 FT	DRAFT AT LCF (H)	=	8.29 FT ABV RRWL
DRAFT AT AP (HA)	=	8.25 FT ABV RRWL	DRAFT AT FP (HF)	=	8.29 FT ABV RRWL

RIGHTING ARMS -VS- HEELS IN INTACT CONDITION

WIND SPEED = 100.00 KNOTS

HEEL :	-15.000	-10.000	-5.000	0.000	10.000	20.000	30.000	40.000	50.000	70.000	80.000	DEGREES
DRAFT:	6.930	7.855	8.210	8.250	7.855	5.098	0.393	-5.472	-13.518	-50.511	-122.869	FEET
TRIM :	0.000	0.000	0.000	0.000	0.000	0.000	0.148	0.147	0.141	-0.122	0.167	FEET
GZ :	-15.994	-12.483	-6.893	0.000	12.483	14.908	10.873	6.610	2.370	-3.609	-4.402	FEET
HARM :	4.739	4.219	3.736	3.257	4.219	5.323	6.446	7.555	8.369	8.742	8.381	FEET

DYNAMIC TRANSVERSE STABILITY

AREA A1 = 4339.33 TON-FT BETWEEN 2.8271 AND 38.2416 DEGREES
AREA A2 = 3058.50 TON-FT BETWEEN -12.1729 AND 2.8271 DEGREES

RATIO A1/A2 = 1.4188 (> 1.4)
PHI-C = 2.8271 DEGREES
RA-C = 3.5291 FT

CRITERIA SATISFIED

NOTE : GZ VALUES INCLUDES CORRECTIONS FOR OFFCENTER WEIGHTS AND FREESURFACE EFFECT FOR LIQUIDES ON BOARD
THE DYNAMIC STABILITY IS BASED ON MAXIMUM POSITIVE HEEL ANGLE OF 38.24 DEGREES

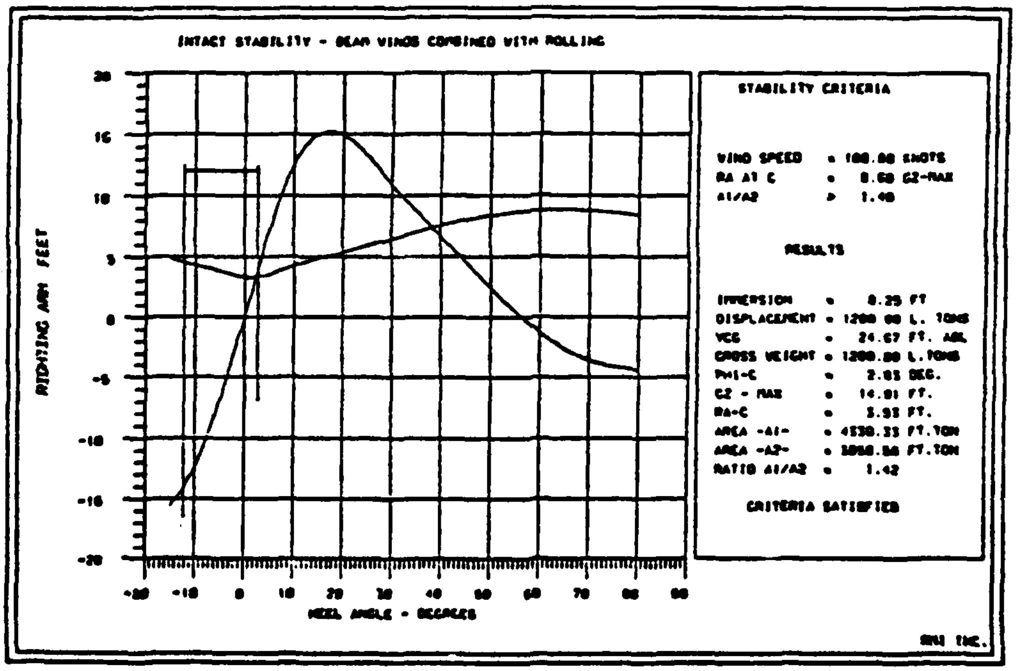


Figure 5.2-13. Transverse Stability in Hullborne Condition with 100 Knots Beam Wind (KG = 23.0 Ft)

INTACT STABILITY

UPRIGHT HYDROSTATIC CHARACTERISTICS

SEA WATER DISPLACEMENT	=	1200.00 TONS	LONGITUDINAL CG (LCG)	=	167.57 FT AFT FP
LONGITUDINAL CB (LCB)	=	167.57 FT AFT FP	LONGITUDINAL CF (LCF)	=	166.34 FT AFT FP
VERTICAL CG (KG)	=	35.00 FT ABV RRWL	VERTICAL CB (KB)	=	5.31 FT ABV RRWL
MAXIMUM FREE-SURFACE	=	2000.00 TON-FT	VERTICAL C.G. (KG)	=	36.67 FT ABV RRWL
TRANSV. METACENTER (KMT)	=	105.47 FT ABV RRWL	LONG. METACENTER (KML)	=	1300.09 FT ABV RRWL
TRANSVERSE CB (TCB)	=	0.00 FT FRM RRVL	MOMENT TO ALTER TRIM (MT1)	=	415.11 TON-FT/INCH
TRIM (+VE : AFTWARD)	=	0.00 FT	DRAFT AT LCF (H)	=	8.25 FT ABV RRWL
DRAFT AT AP (HA)	=	8.25 FT ABV RRWL	DRAFT AT FP (HF)	=	8.25 FT ABV RRWL

RIGHTING ARMS -VS- HEELS IN INTACT CONDITION

WIND SPEED = 70.00 KNOTS

HEEL :	-15.000	-10.000	-5.000	0.000	10.000	20.000	30.000	40.000	50.000	70.000	80.000	DEGREES
DRAFT:	6.930	7.855	8.210	8.250	7.855	5.098	0.393	-5.472	-13.518	-50.811	-122.869	FEET
TRIM :	0.000	0.000	0.000	0.000	0.000	0.000	0.148	0.147	0.141	-0.122	0.167	FEET
GZ :	-12.499	-10.400	-5.847	0.000	10.400	10.803	4.874	-1.102	-6.821	-14.881	-16.220	FEET
HARM :	2.322	2.067	1.830	1.596	2.067	2.608	3.159	3.702	4.099	4.283	4.107	FEET

DYNAMIC TRANSVERSE STABILITY

AREA A1 = 3348.48 TON-FT BETWEEN 1.6075 AND 32.6316 DEGREES
AREA A2 = 2321.05 TON-FT BETWEEN -13.3925 AND 1.6075 DEGREES

RATIO A1/A2 = 1.4075 (> 1.4)
PHI-C = 1.6075 DEGREES
RA-C = 1.6718 FT

CRITERIA SATISFIED

NOTE : GZ VALUES INCLUDES CORRECTIONS FOR OFFCENTER WEIGHTS AND FREESURFACE EFFECT FOR LIQUIDES ON BOARD
THE DYNAMIC STABILITY IS BASED ON MAXIMUM POSITIVE HEEL ANGLE OF 32.63 DEGREES

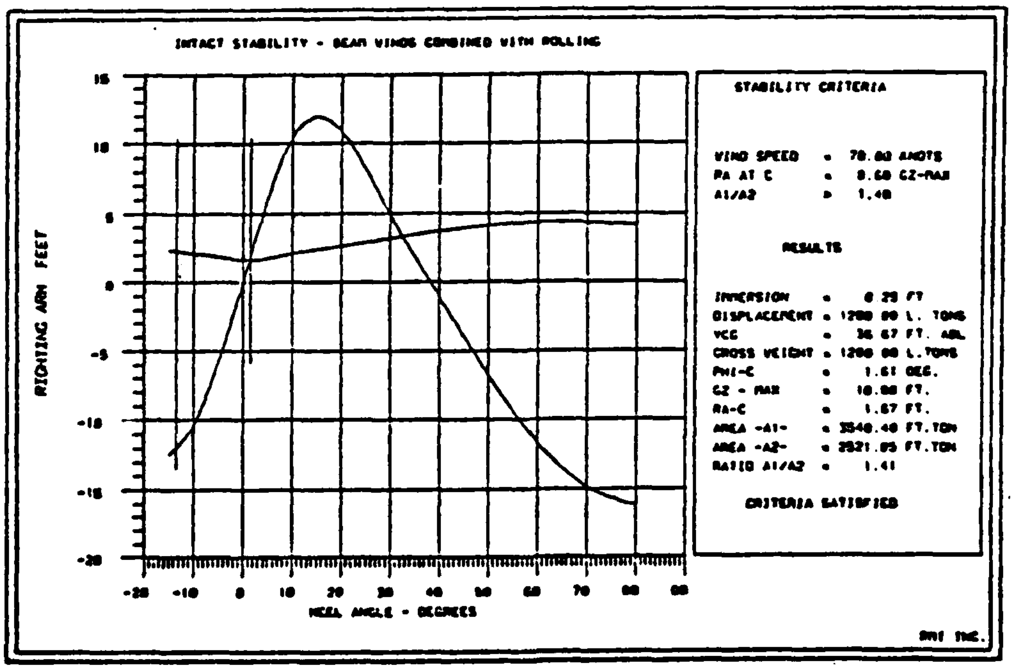


Figure 5.2-14. Transverse Stability in Hullborne Condition with 70 Knots Beam Winds (KG = 35.0 FT)

INTACT STABILITY

UPRIGHT HYDROSTATIC CHARACTERISTICS

SEA WATER DISPLACEMENT	= 86.42 TONS		LONGITUDINAL CG (LCG)	=	168.78 FT AFT FP
LONGITUDINAL CB (LCB)	= 168.78 FT AFT FP		LONGITUDINAL CF (LCF)	=	168.42 FT AFT FP
VERTICAL CG (KG)	= 30.00 FT ABV RRWL		VERTICAL CB (KB)	=	1.27 FT ABV RRWL
MAXIMUM FREE-SURFACE	= 2000.00 TON-FT		VERTICAL C.G. (KG)	=	31.67 FT ABV RRWL
TRANSV. METACENTER (KMT)	= 358.92 FT ABV RRWL		LONG. METACENTER (KML)	=	5871.02 FT ABV RRWL
TRANSVERSE CG (TCG)	= 0.00 FT FRM RRVL		MOMENT TO ALTER TRIM (MTI)	=	135.52 TON-FT/INCH
TRIM (+VE : AFTWARD)	= 0.00 FT		DRAFT AT LCF (H)	=	2.00 FT ABV RRWL
DRAFT AT AP (HA)	= 2.00 FT ABV RRWL		DRAFT AT FP (HF)	=	2.00 FT ABV RRWL

RIGHTING ARMS -VS- HEELS IN INTACT CONDITION

WIND SPEED = 10.00 KNOTS

HEEL :	-15.000	-10.000	-5.000	0.000	10.000	20.000	30.000	40.000	50.000	70.000	80.000	DEGREES
DRAFT:	-2.717	-0.748	1.114	2.000	-0.748	-4.858	-9.846	-16.104	-25.181	-67.716	-150.444	FEET
TRIM :	0.000	-0.119	0.000	0.000	0.000	-0.049	-0.197	-0.277	-0.335	-0.375	-0.380	FEET
GZ :	-11.857	-14.489	-17.137	0.000	14.491	9.407	5.565	1.977	-3.242	-14.185	-18.148	FEET
WARM :	0.626	0.529	0.433	0.351	0.528	0.723	0.905	1.033	1.174	1.239	1.198	FEET

DYNAMIC TRANSVERSE STABILITY

AREA A1 = 5799.61 TON-FT BETWEEN 0.2451 AND 41.7612 DEGREES
AREA A2 = 4020.92 TON-FT BETWEEN -14.7549 AND 0.2451 DEGREES

RATIO A1/A2 = 1.4424 (> 1.4)
PHI-C = 0.2451 DEGREES
RA-C = 0.3551 FT

CRITERIA SATISFIED

NOTE : GZ VALUES INCLUDES CORRECTIONS FOR OFFCENTER WEIGHTS AND FREESURFACE EFFECT FOR LIQUIDES ON BOARD
THE DYNAMIC STABILITY IS BASED ON MAXIMUM POSITIVE HEEL ANGLE OF 41.76 DEGREES

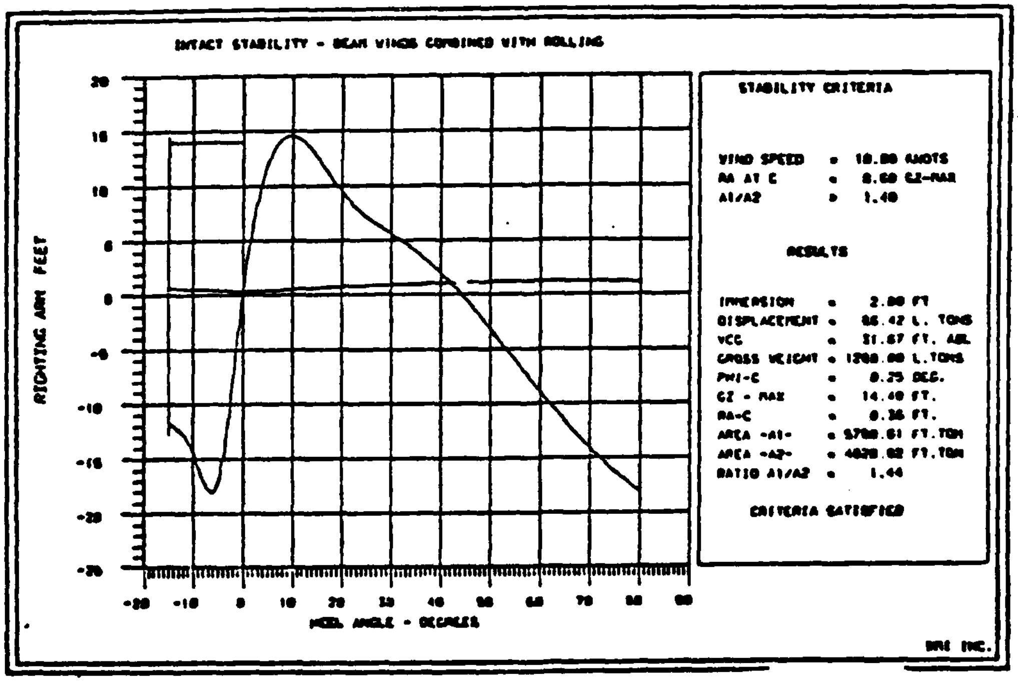


Figure 5.2-15. Transverse Stability in On-Cushion Hover Mode with 10 Knots Beam Wind (KG = 30.0 Ft)

INTACT STABILITY

UPRIGHT HYDROSTATIC CHARACTERISTICS

SEA WATER DISPLACEMENT	=	86.42 TONS	LONGITUDINAL CG (LCG)	=	160.78 FT AFT FP
LONGITUDINAL CB (LCB)	=	163.73 FT AFT FP	LONGITUDINAL CF (LCF)	=	160.42 FT AFT FP
VERTICAL CG (KG)	=	20.00 FT ABV RRWL	VERTICAL CB (KB)	=	1.27 FT ABV RRWL
MAXIMUM FREE-SURFACE	=	2000.00 TON-FT	VERTICAL C.G. (KG)	=	21.67 FT ABV RRWL
TRANSV. METACENTER (KMT)	=	353.92 FT ABV RRWL	LONG. METACENTER (KML)	=	5871.02 FT ABV RRWL
TRANSVERSE CG (TCG)	=	0.00 FT FRM RRWL	MOMENT TO ALTER TRIM (MTI)	=	135.52 TON-FT/INCH
TRIM (+VE : AFTWARD)	=	0.00 FT	DRAFT AT LCF (H)	=	2.00 FT ABV RRWL
DRAFT AT AP (HA)	=	2.00 FT ABV RRWL	DRAFT AT FP (HF)	=	2.00 FT ABV RRWL

RIGHTING ARMS -VS- HEELS IN INTACT CONDITION

WIND SPEED = 22.00 KNOTS

HEEL :	-15.000	-10.000	-5.000	0.000	10.000	20.000	30.000	40.000	50.000	70.000	80.000	DEGREES
DRAFT:	-2.717	-0.748	1.114	2.000	-0.748	-4.855	-9.846	-16.104	-25.181	-67.716	-130.444	FEET
TRIM :	0.000	-0.119	0.000	0.000	0.000	-0.049	-0.197	-0.277	-0.335	-0.375	-0.380	FEET
GZ :	-14.445	-16.225	-18.008	0.000	16.227	12.827	10.565	8.404	4.418	-4.789	-8.300	FEET
HARM :	3.022	2.561	2.093	1.698	2.557	3.498	4.383	5.000	5.604	5.975	5.604	FEET

DYNAMIC TRANSVERSE STABILITY

AREA A1 = 6569.80 TON-FT BETWEEN 1.1048 AND 47.2886 DEGREES
AREA A2 = 4687.79 TON-FT BETWEEN -13.0952 AND 1.1048 DEGREES

RATIO A1/A2 = 1.4015 (> 1.4)
PHI-C = 1.1048 DEGREES
RA-C = 1.7927 FT

CRITERIA SATISFIED

NOTE : GZ VALUES INCLUDES CORRECTIONS FOR OFFCENTER WEIGHTS AND FREESURFACE EFFECT FOR LIQUIDES ON BOARD
THE DYNAMIC STABILITY IS BASED ON MAXIMUM POSITIVE HEEL ANGLE OF 47.29 DEGREES

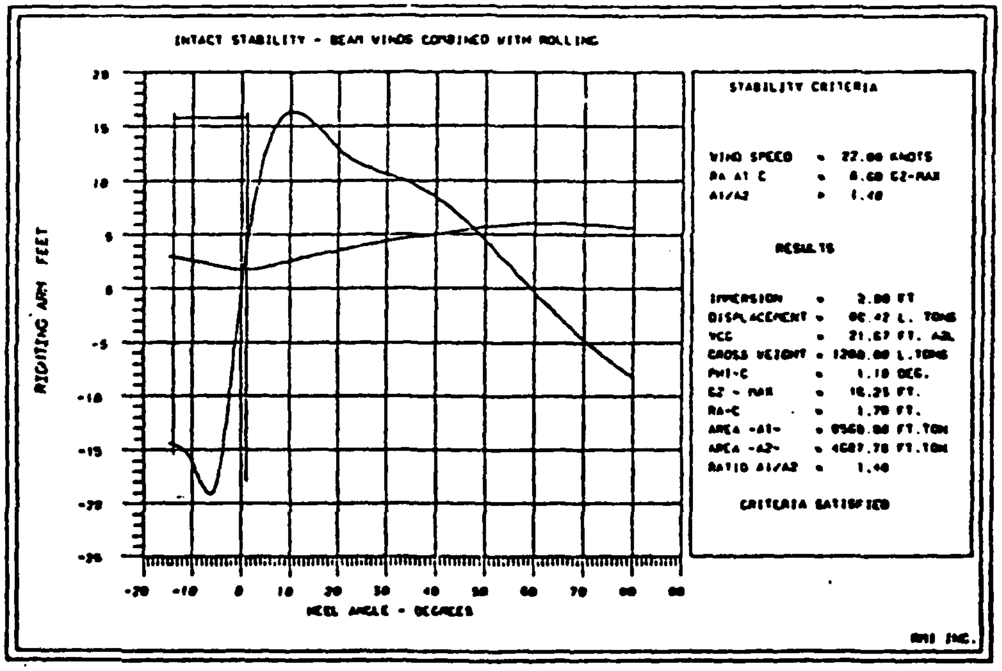


Figure 5.2-16. Transverse Stability in On-Cushion Hover Mode with 22 Knots Beam Wind (KG = 20.0 Ft)

Ride control is accomplished by modulation of the cushion air flow to minimize the pressure fluctuations resulting from the passage of sea waves. The flow control is accomplished by several means such as:

a. Fast response hydraulically actuated vent valves which regulate the cushion air flow through plenum exhaust control.
b. Variable flow fans with hydraulically actuated inlet vanes which regulate the cushion air flow through control of the air input supply.

The details of the ride control system are discussed in Paragraph 6.2.5. The analysis of ship motions and ride quality are discussed below.

5.3.1 RIDE QUALITY ANALYSIS -- The results of the ride quality analysis conducted for each of the four USCG designs for representative operational speeds and sea states are shown in Figures 5.3-1 through 5.3-4. The criteria for motion sickness and operator efficiency shown on the charts were derived within the course of the U.S. Navy 3KSES development program. A discussion of the development of these criteria is presented in Reference 5-7. The results of the analysis show that with the utilization of ride control systems, a satisfactory ride quality should be provided by each of the four USCG SES designs. It should be noted that the motion characteristics shown in Figure 5.3-1 through 5.3-4 were computed for the worst case, head sea condition. Model tests have shown that the adjustment of ship's course by approximately 30 degrees to avoid the head sea condition will significantly reduce the magnitude of vertical accelerations.

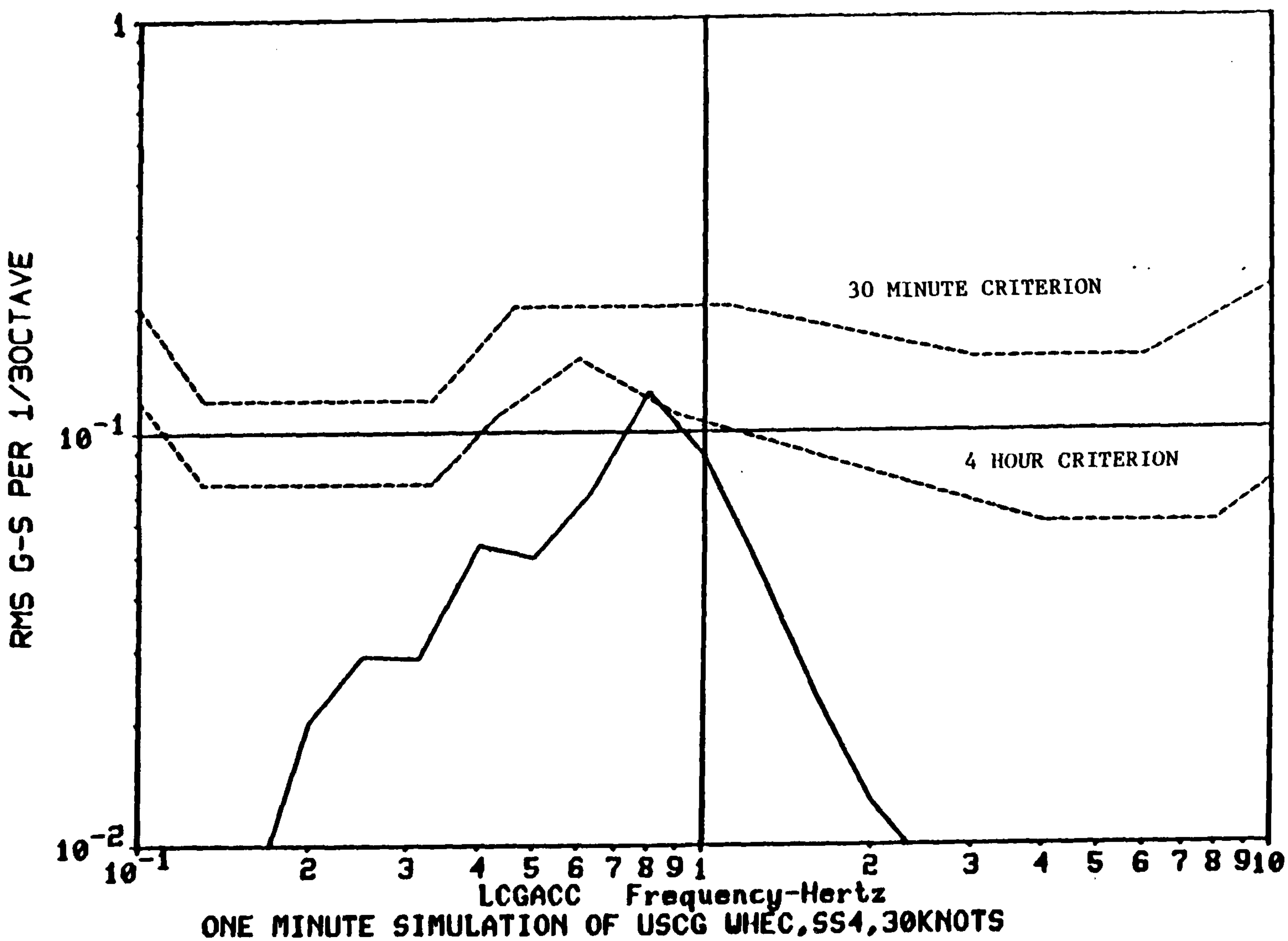


Figure 5.3-1. WHEC-SES Ride Quality - 30 Knots in Sea State 4 - Cushionborne with Ride Control

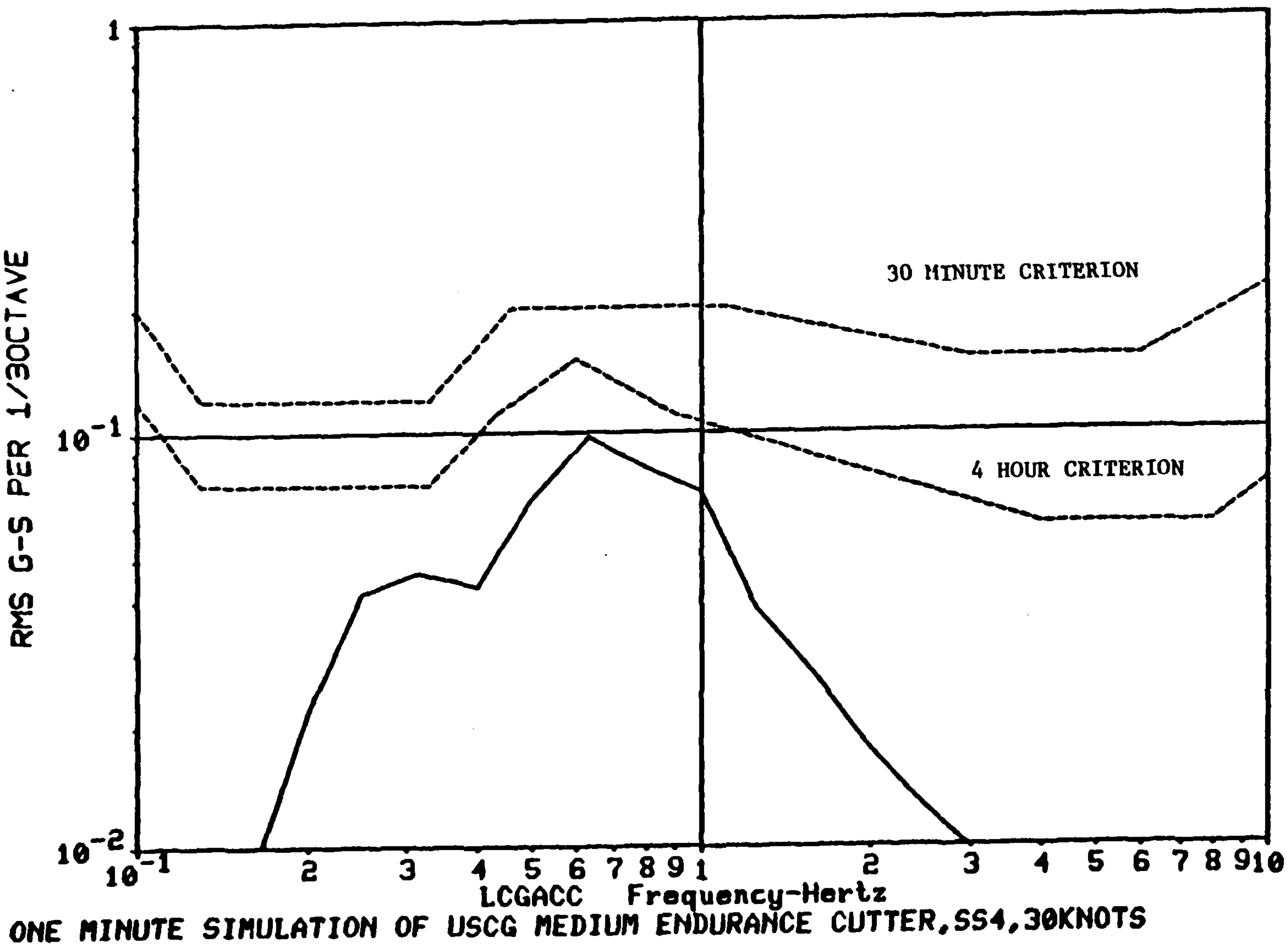


Figure 5.3-2. WMEC-SES Ride Quality - 30 Knots - Sea State 4 - Cushionborne with Ride Control

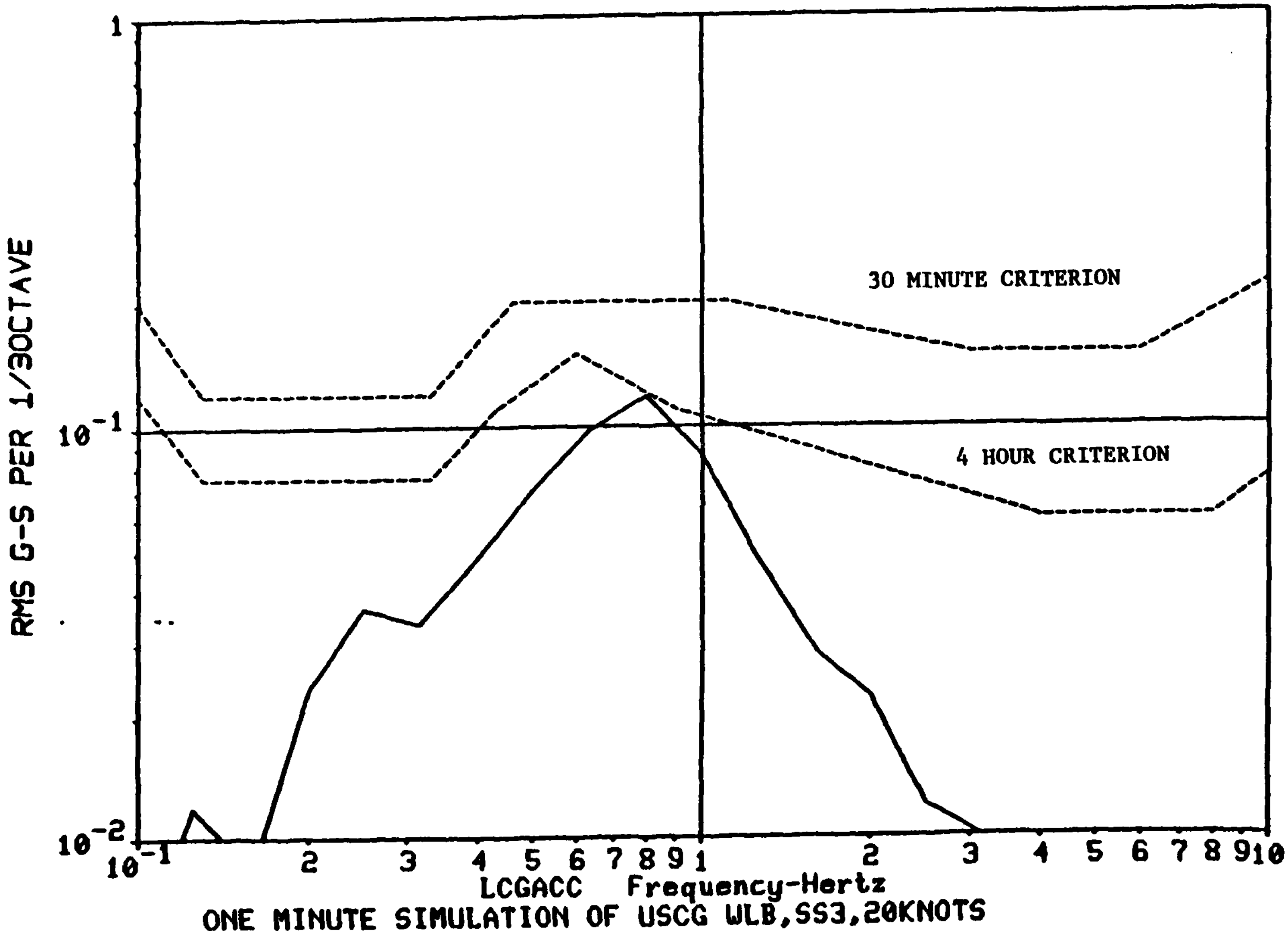


Figure 5.3-3. WLB-SES Ride Quality - 20 Knots - Sea State 3 - Cushionborne with Ride Control

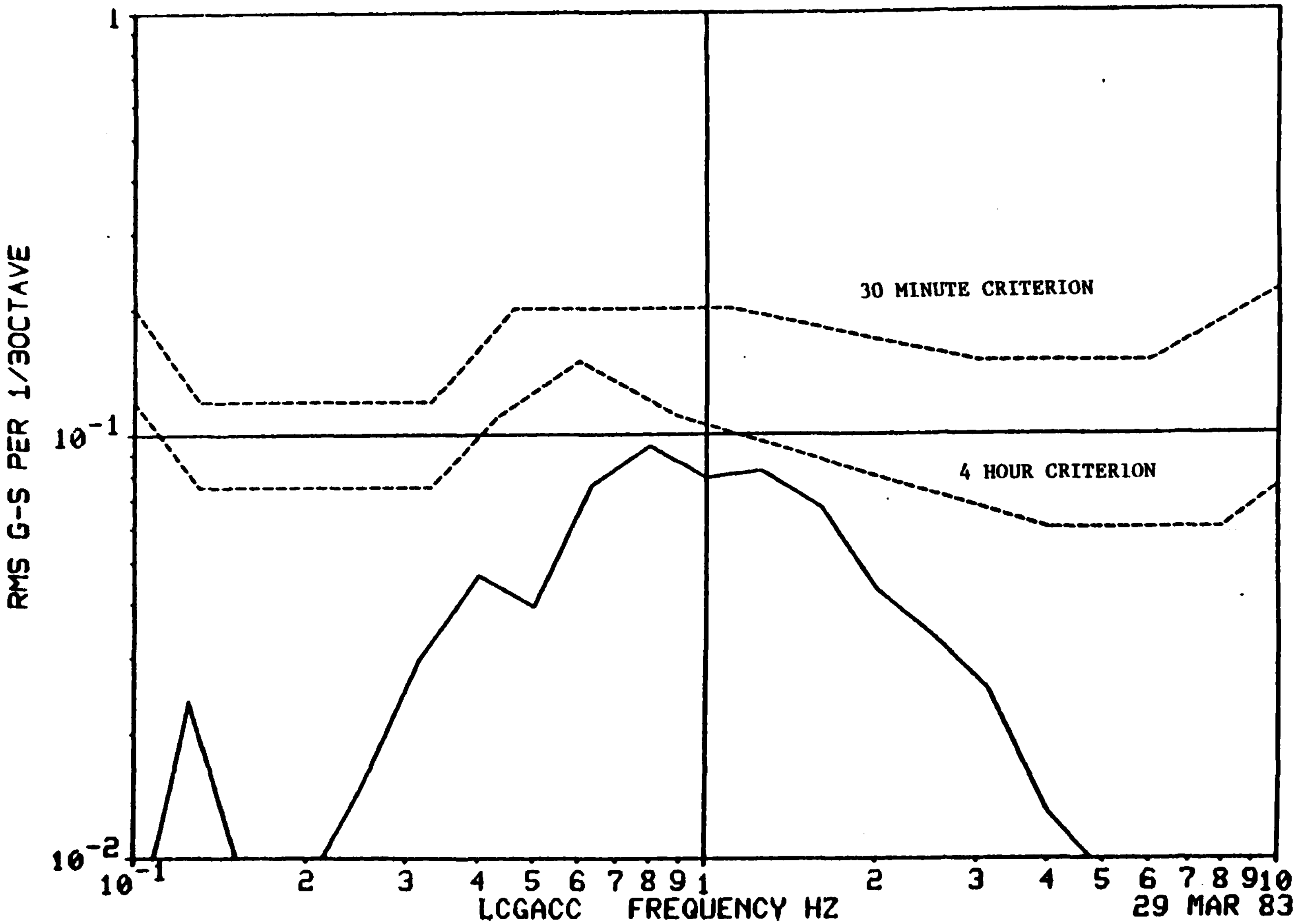


Figure 5.3-4. WPC-SES Ride Quality - 30 Knots - Sea State 3 - Cushionborne with Ride Control

6. SUBSYSTEM ANALYSIS

This section presents the analysis performed in the development of the major systems for each of the USCG SES designs.

6.1 HULL STRUCTURE

The functional requirements of the hull structural subsystems are (1) to provide a watertight envelope which houses all other subsystems in a manner suitable to the performance goals of the craft, (2) provide an envelope suitable for accomodation of ship's personnel and (3) provide a platform for the installation and operation of mission related equipment.

For each ship concept, the development of the hull structure design comprised four elements:

a. The selection of primary structural geometry to satisfy the ship arrangement requirements.
b. The estimation of primary structural loads.
c. The determination of scantlings of primary structure to satisfy the strength requirements.
d. The incorporation of producibility considerations in the selection of structural parts arrangement and joint design.

6.1.1 *STRUCTURE DESCRIPTION* -- The hull girder of each of the design concepts is made up of two longitudinal watertight bulkheads, transverse bulkheads, shell plating and internal decks. Transverse frames are spaced between transverse bulkheads. Flat bar stiffeners are utilized for longitudinal structure and tee section stiffeners for the stiffening of transverse bulkheads. Typical hull cross-sections for the four design concepts are shown in Figures 6.1-1 through 6.1-4.

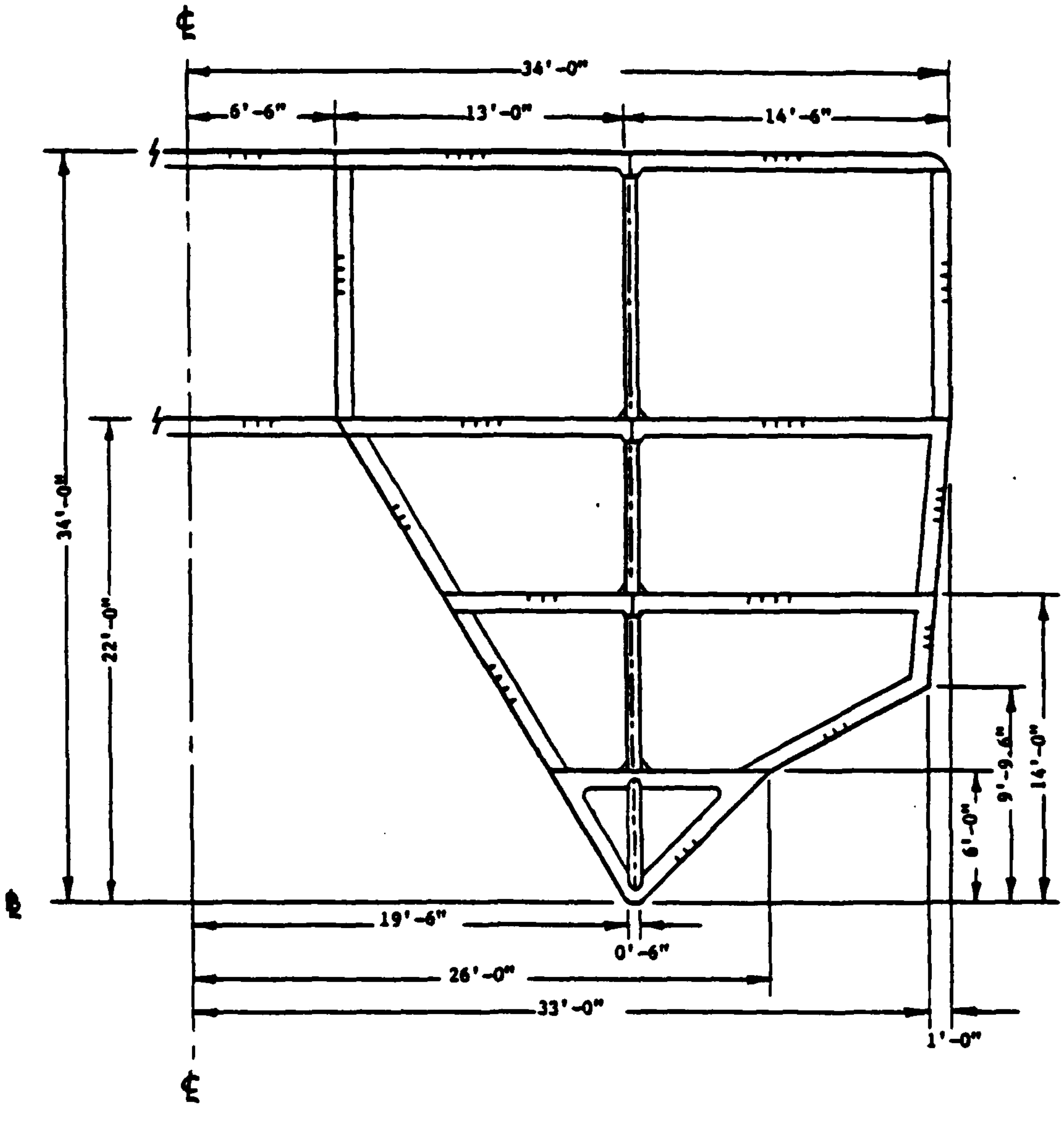


Figure 6.1-1. Midship Section - WHEC-SES

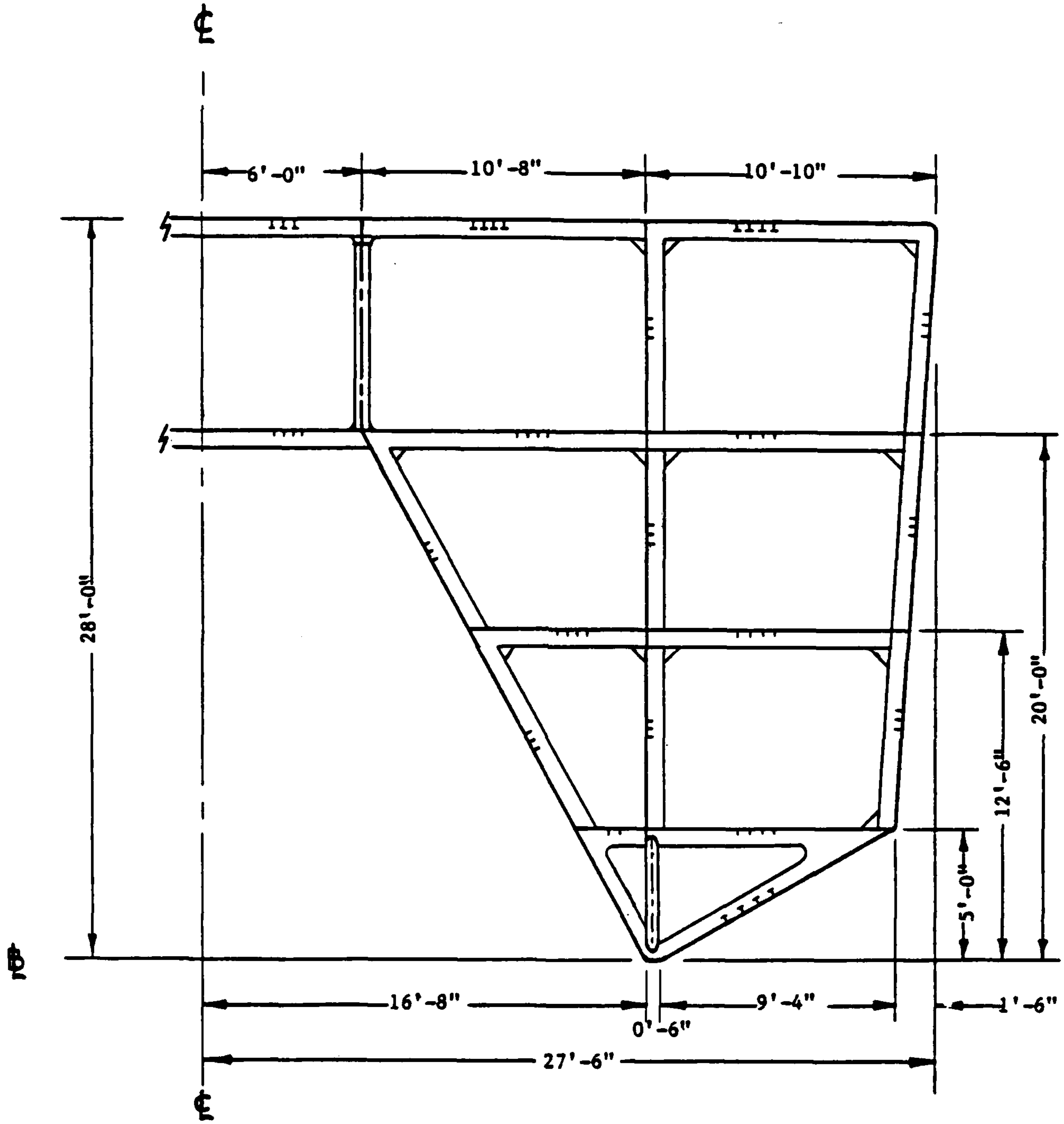


Figure 6.1-2. Midship Section - WMEC-SES

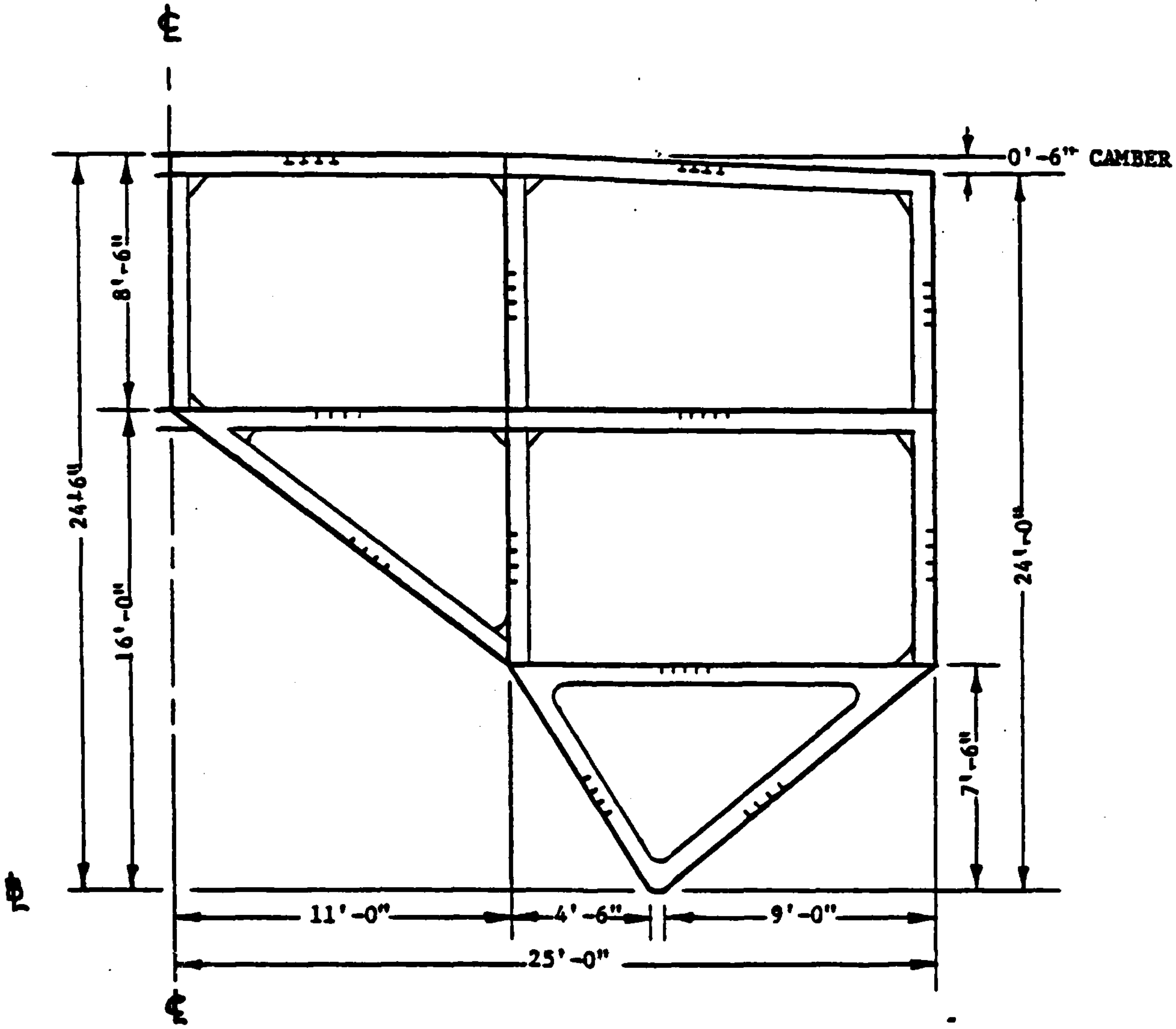


Figure 6.1-3 Midship Section - WLB-SES

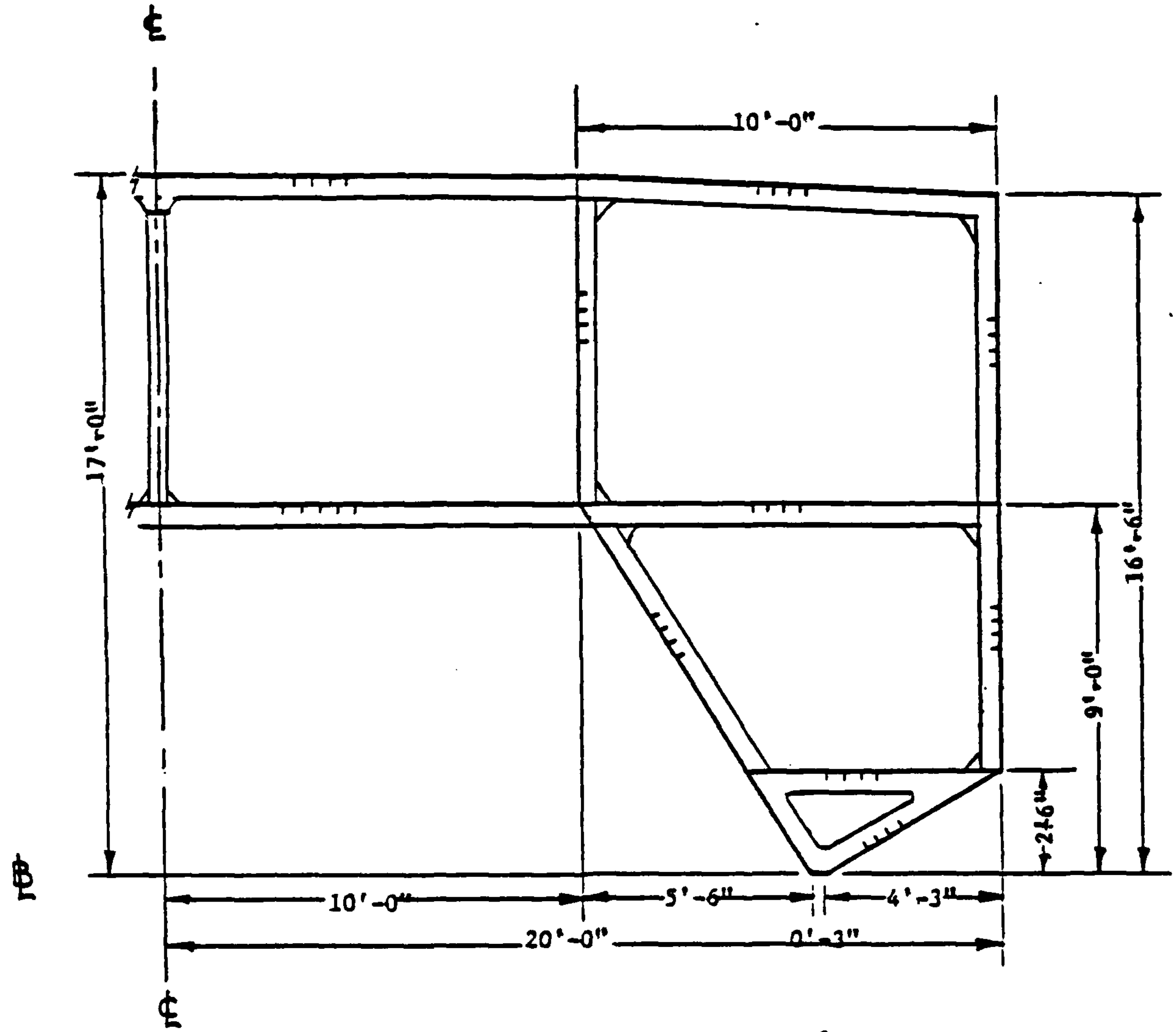


Figure 6.1-4. Midship Section - WPC-SES

With the exception of the WHEC and the WLB all ship hulls are constructed of welded 5456 aluminum alloy. The hull structures of the WHEC and the WLB are constructed of high strength steel. The internal decks of the WLB are constructed of lightweight honeycomb panels in regions where the decks do not carry primary hull loads. A typical structural detail of the honeycomb deck installation is shown in Figure 6.1-5.

6.1.2 STRUCTURAL PRODUCIBILITY -- The selected structural arrangements were based upon the producibility lessons learned through the U.S. Navy 3KSES program and other modern lightweight high performance ship programs. The improvements include simplified stiffened bulkhead construction using welded tee extrusions with low-moment end connections, the use of efficient, lightweight flat bar stiffening on longitudinal plating, simple transverse framing connections, flat panel plating and a high measure of accessibility for welding and inspection.

6.1.3 STRUCTURAL LOADS ESTIMATE -- The structural loads are predicted using the scaled results from a structural loads test using a structurally scaled model. The results were analyzed to obtain the most probable lifetime load (Lmp) at the expected lifetime number of pitch cycles. Since the most probable lifetime load is exceeded about 63 percent of the time in a sample containing a large number of ships, the most probable lifetime load is then multiplied by a factor F.999 so that only one in a thousand ships operating in similar conditions would experience a load greater than LF = Lmp F.999 and would be expected to incure some significant structural damage. LF is the load associated with a risk of 0.001 and is equal to the design load (LD) multiplied by the factor of safety (FOS). See Figure 6.1-6.

The model test data were obtained from a structural loads test performed in Oct-Nov 1981 using a 12-foot long surface effect ship (SES) model having a cushion length-to-beam (L/B) ratio of 7.5 (References 2-5).

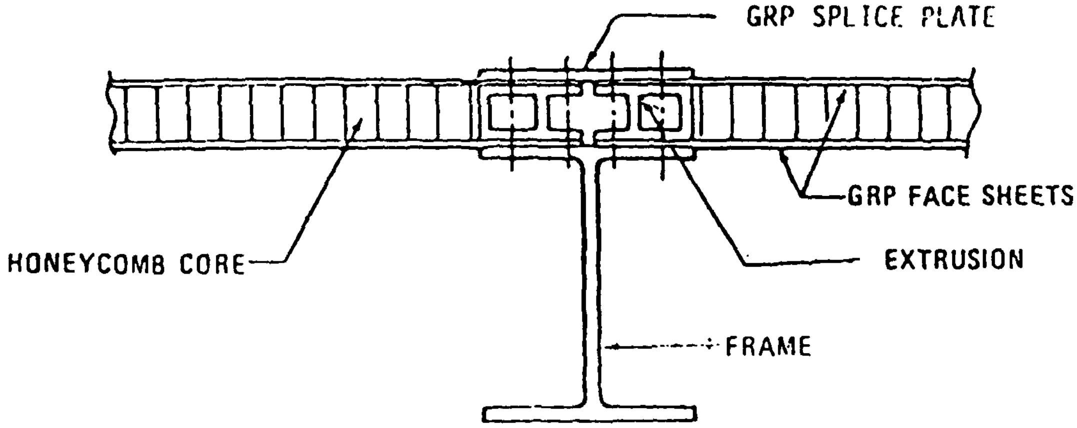


Figure 6.1-5. GRP Sandwich Panel Supported by Steel (or Aluminum) Frame

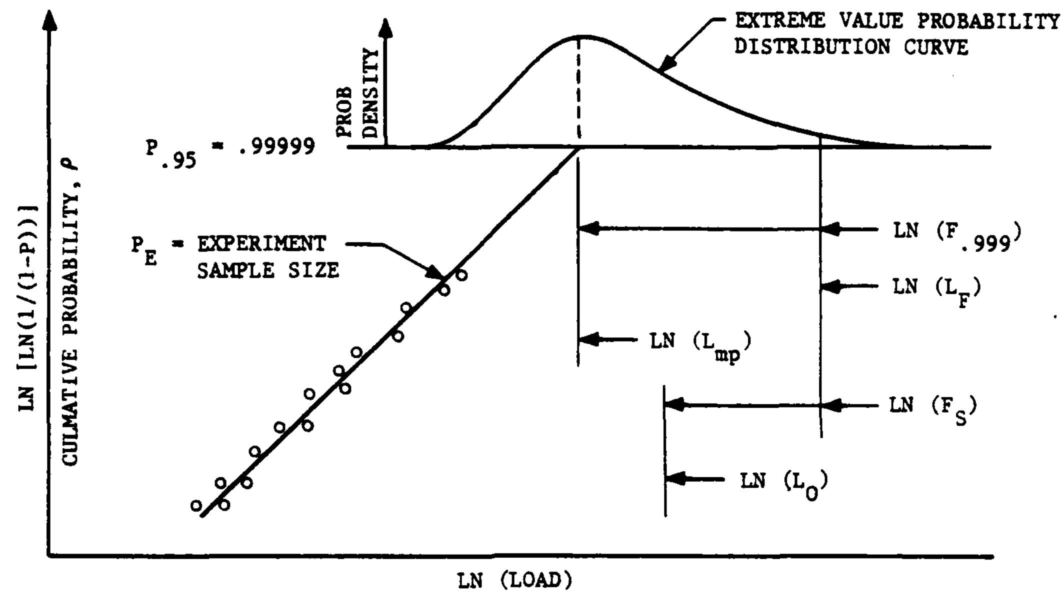


Figure 6.1-6. Relationship Between L_{mp}, F_{999}, L_F, F_S and L_D

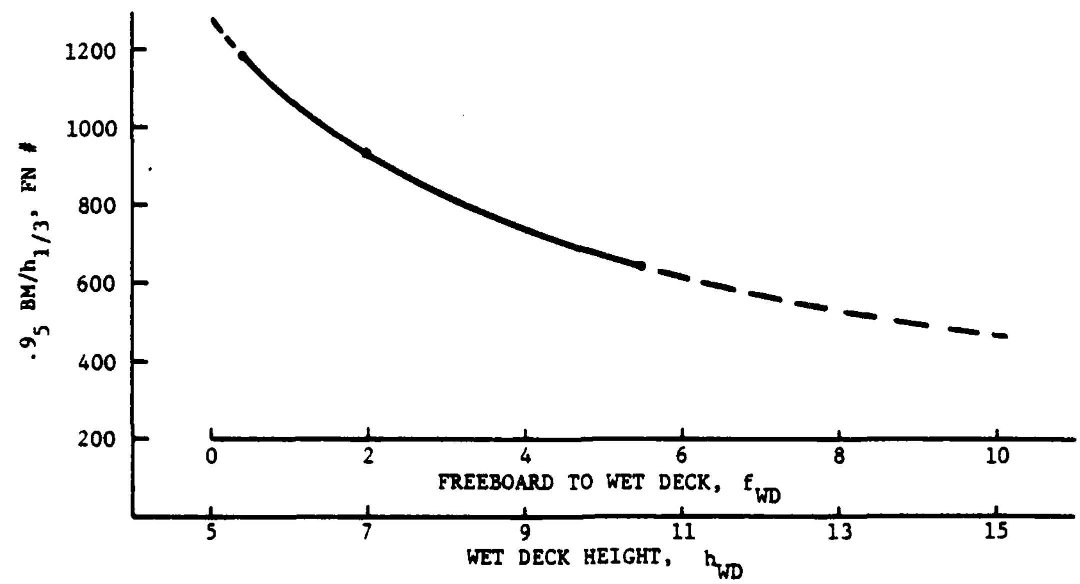


Figure 6.1-7. Wet Deck Freeboard Effect Upon BM

The model was constructed so that the wet deck height, and thus the calm water deck height clearance (i.e. freeboard to wet deck) could be varied while keeping the model weight constant. The model was also constructed to have the Froude scaled elastic response associated with an SES of approximately 1500 long tons. The model instrumentation consisted of strain gages to measure the longitudinal distribution of bending moment, pressure gages to measure local pressures in the bow and stern accelerometers, and pitch and heave indicators.

The model was tested hullborne and cushionborne at several speeds in a random seaway having various wave heights.

The maximum values of the bending moments and pressures occurring during each pitch cycle were found and plotted using a nonlinear transform such that if the maxima follow a Weibull distribution the Maxima plot has a straight line. On a Weibull plot the vertical axis is cumulative probability and is indicative of the total number events, while the horizontal axis is the load value. The most probable value of the load for a given number of events (in our case, the number of pitch cycles) then can be found by extrapolating the line fitted through the maximum points. Figure 6.1-6, without the superimposed extreme value probability distribution curve, is an example of a Weibull plot.

The effect of wet deck height on bending load is estimated by use of Figure 6.1-7. Figure 6.1-7 is derived from using test points corresponding to different, as tested, wet deck heights at approximately the same significant wave height and speed with the craft in the hullborne mode. The results are extrapolated to 100,000 pitch cycles and the resulting bending moment (BM) is then divided by the significant wave height and plotted against calm water freeboard to wet deck ratio f_{WD}.

Figure 6.1-7 is used to estimate model loads as follows:

a. Find f_{WD} full size using the sidewall shape and the displacement of the craft.

b. using the longitudinal scale ratio λL find f_{WD} model scale.

c. read the value of BM/h1/3 model scale.

d. using λL find h1/3 model scale.

e. estimate BM model scale by forming $BM_{MS} = (BM/h_{1/3})\ h_{1/3}$.

The result is an estimate of the BM model scale at the particular wet deck clearance f_{WD} and significant wave height $h_{1/3}$ corresponding to the full size vessel desired.

Scaling to full size is accomplished by Froude scaling as follows:

a. find the longitudinal and transverse scale ratios λL and λB which corresponds to the characteristics length for slamming.

b. for $BM_{FS} = [BM/_{MS} (\lambda L^3) (\lambda_B)] \cdot F_E$. Where F_E is the exposure factor relating BM_{FS} (which is the 100,000 pitch cycle estimate) to the actual number of exposures.

The exposure factor F_E is found by referring to the Weibull plot and reading the load corresponding to the actual number of pitch cycles. $BM_A F_E$ then equals BM_A/BM_{MS} and becomes L_{MP} for bending moment. The final step in finding the load $L_F = L_{MP}$ F.999 is to determine what factor F.999 is required to cover 0.999 of the extreme value curve if no resistance probability curve is available, or to have the risk area of the extreme value curve-resistance curve equal 0.001 if a resistance curve is available.

The resulting design criteria derived for each of the USCG ship designs are discussed in the following paragraphs.

6.1.4 STRUCTURAL DESIGN CRITERIA — The structure design of the four USCG designs developed through the process discussed above are summarized below:

a. WHEC - SES - Figures 6.1-8 and 6.1-9
b. WMEC - SES - Figures 6.1-10 and 6.1-11
c. WLB - SES - Figures 6.1-12 and 6.1-13
d. WPC - SES - Figures 6.1-14 and 6.1-15

6.1.5 MATERIAL ALLOWABLES — Material property allowable for the aluminum alloy materials were obtained from material specifications and Aluminum Association technical information. Table 6.1-1 summarizes the properties for unwelded and welded 5456 aluminum alloy. Table 6.1-2 summarizes the properties of high strength, low alloy steel.

The as-welded yield strength of aluminum, as used in this report, was determined from a 10-inch extensometer spanning a transverse butt-weld joint. The yield strength indicated by the 10-inch extensometer data has been adopted for usage by the Aluminum Association. This yield strength is closely representative of an effective panel yield strength. It has been substantiated by extensive testing which demonstrated that when the actual 10-inch extensometer data were used for predicting panel buckling strength, the predicted values were conservative, being from 1 to 6 percent below the actual strengths (Reference 2-9).

6.1.6 STRUCTURAL ANALYSIS — Structural analysis was accomplished by accepted methods documented in textbooks, Navy design data sheets, or published technical articles.

To determine longitudinal scantlings, sections were analyzed for external bending moment and shear. Internal load distributions were determined for the midship hull section as a function of external loads, ship geometry, and material distribution. The plate loads and pressures or local loads were combined to compute plating sizes for decks, longitudinal bulkhead and outer shell plating.

SLAM PRESSURES ARE NOT COMBINED
WITH HULL GIRDER LOADS

LOCAL LOADS (OTHER THAN
SLAMMING) ARE COMBINED WITH
HULL GIRDER LOADS

LOCAL LOADS INCLUDE DECK
LIVE LOADS: 75 PSF (TOP OF DK HSE)
150 PSF (LIVING, OFFICE SPACES)
200 PSF (MACHINERY SPACES)

USE 50% OF SLAM PRESSURE FOR FRAME DESIGN

SAFETY FACTORS	YIELD	ULT.
HULLBORNE + LOCAL LOADS	1.2	1.5
CUSHIONBORNE + LOCAL LOADS	1.2	1.5
*SLAMMING PRESSURES	1.0	1.2

*PERMANENT SET TO
A MAXIMUM OF PLATE
THICKNESS IS ALLOWED

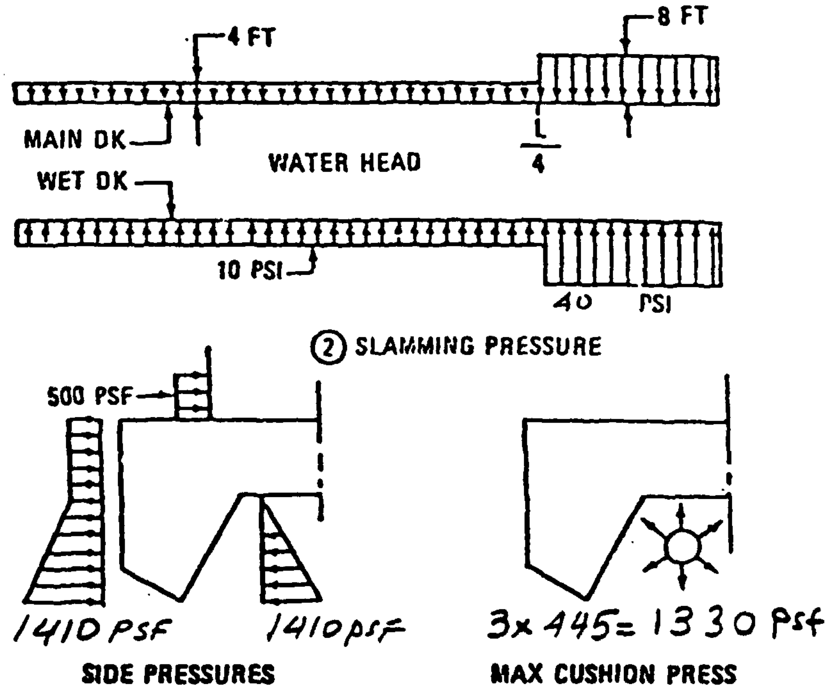


Figure 6.1-8. WHEC-SES Hull Design Criteria

AD-A158 200 CONCEPTUAL DESIGN OF FOUR SURFACE EFFECT SHIPS FOR US COAST GUARD APPLICATIONS(U) COAST GUARD WASHINGTON DC OFFICE OF RESEARCH AND DEVELOPMENT MAY 85 USCG-D-13-85

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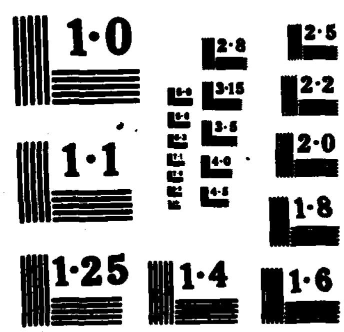
1·0
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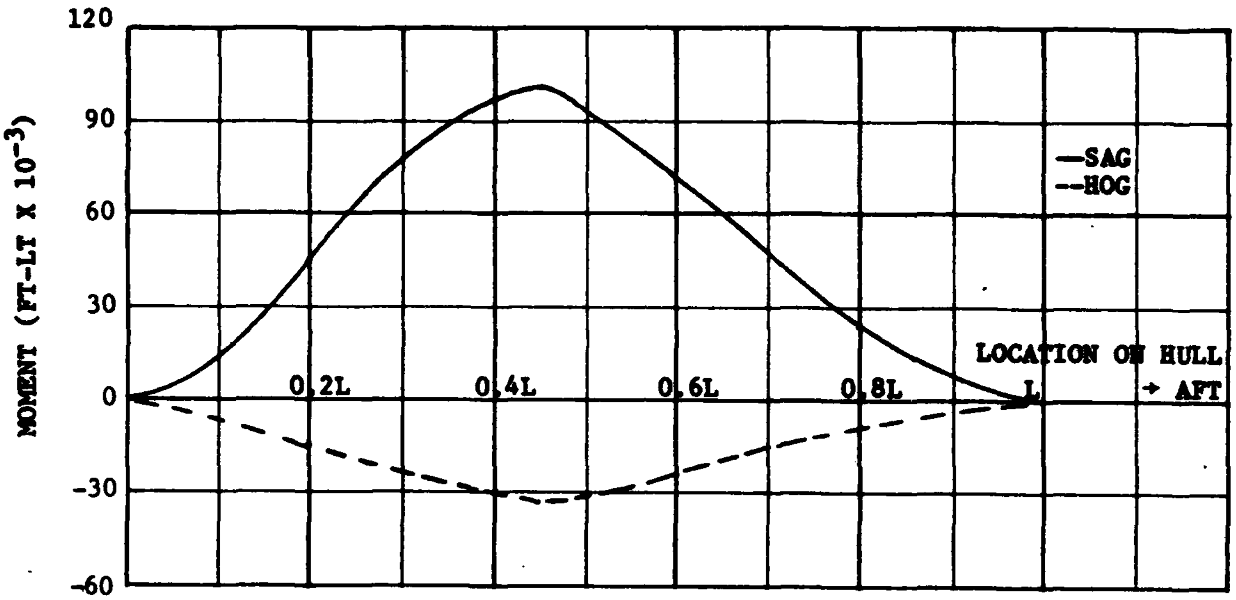
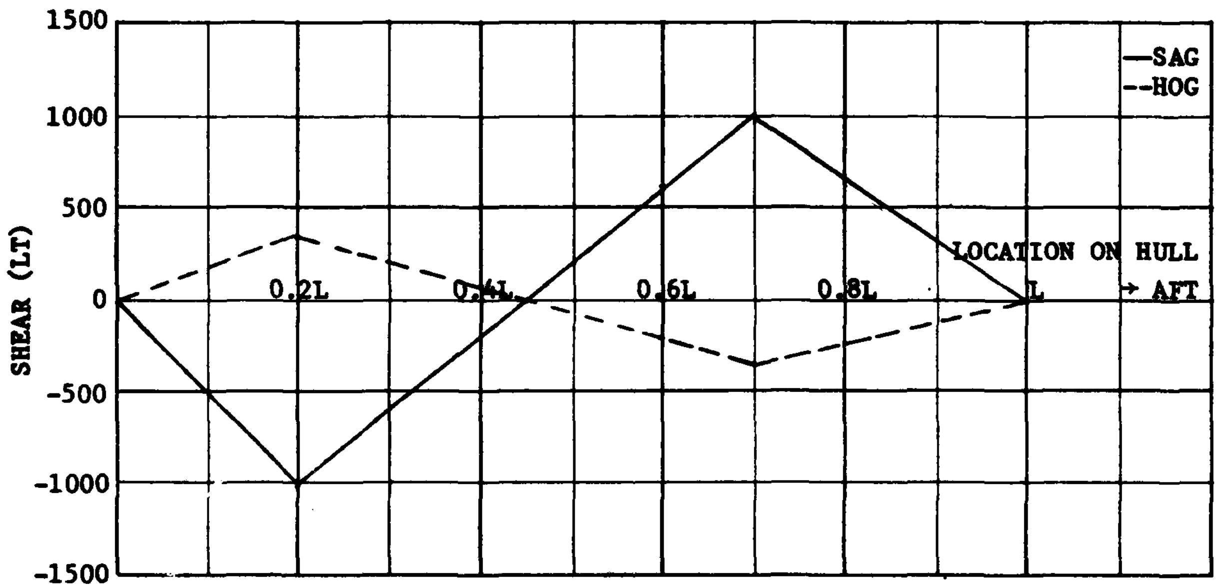


HULLBORNE BENDING MOMENT



HULLBORNE SHEAR

Safety Factor - SF Yield = 1.2
SF ULT = 1.5

Figure 6.1-9. WHEC-SES Design Shear and Bending Moment Envelopes

SLAM PRESSURES ARE NOT COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS (OTHER THAN SLAMMING) ARE COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS INCLUDE DECK LIVE LOADS: 75 PSF (TOP OF DK HSE)
150 PSF (LIVING, OFFICE SPACES)
200 PSF (MACHINERY SPACES)

USE 50% OF SLAM PRESSURE FOR FRAME DESIGN

SAFETY FACTORS	YIELD	ULT.
HULLBORNE + LOCAL LOADS	1.2	1.5
CUSHIONBORNE + LOCAL LOADS	1.2	1.5
*SLAMMING PRESSURES	1.0	1.2

*PERMANENT SET TO A MAXIMUM OF PLATE THICKNESS IS ALLOWED

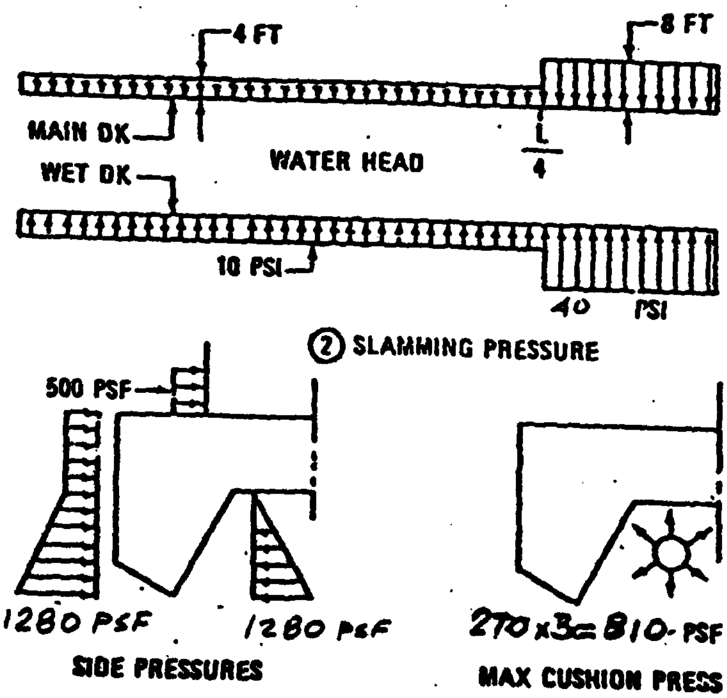
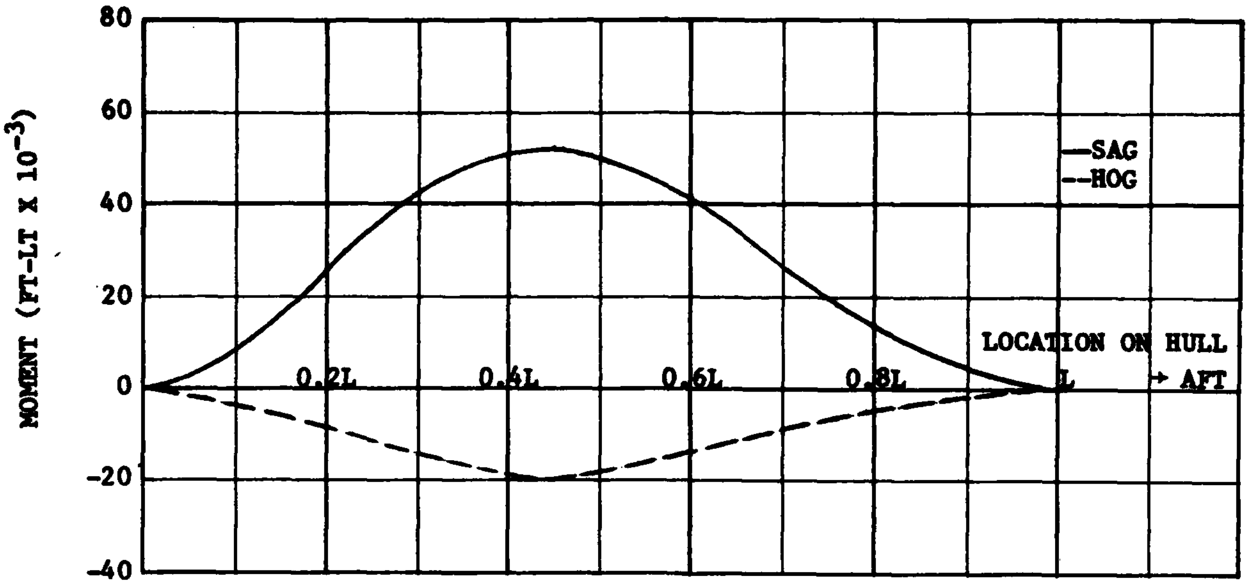
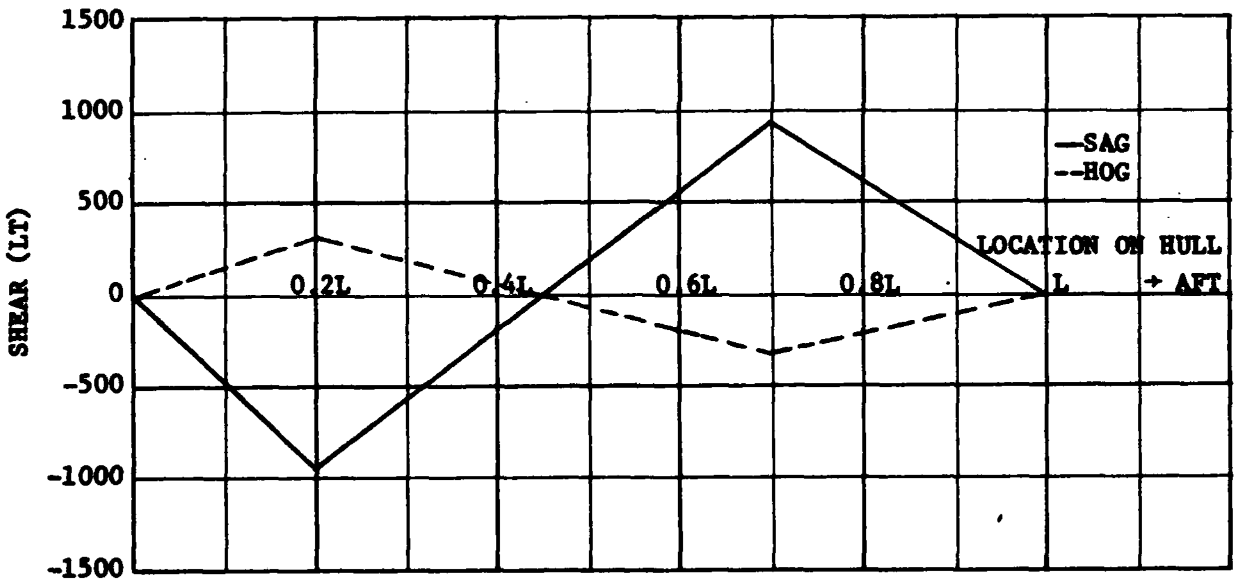


Figure 6.1-10. WMEC-SES Hull Design Criteria



HULLBORNE BENDING MOMENT



HULLBORNE SHEAR

Safety Factors - SF Yield = 1.2
SF ULT = 1.5

Figure 6.1-11. WMEC-SES Design Shear and Bending Moment Envelopes

SLAM PRESSURES ARE NOT COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS (OTHER THAN SLAMMING) ARE COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS INCLUDE DECK LIVE LOADS: 75 PSF (TOP OF DK HSE)
150 PSF (LIVING, OFFICE SPACES)
200 PSF (MACHINERY SPACES)

USE 50% OF SLAM PRESSURE FOR FRAME DESIGN

SAFETY FACTORS	YIELD	ULT.
HULLBORNE + LOCAL LOADS	1.2	1.5
CUSHIONBORNE + LOCAL LOADS	1.2	1.5
*SLAMMING PRESSURES:	1.0	1.2

*PERMANENT SET TO A MAXIMUM OF PLATE THICKNESS IS ALLOWED

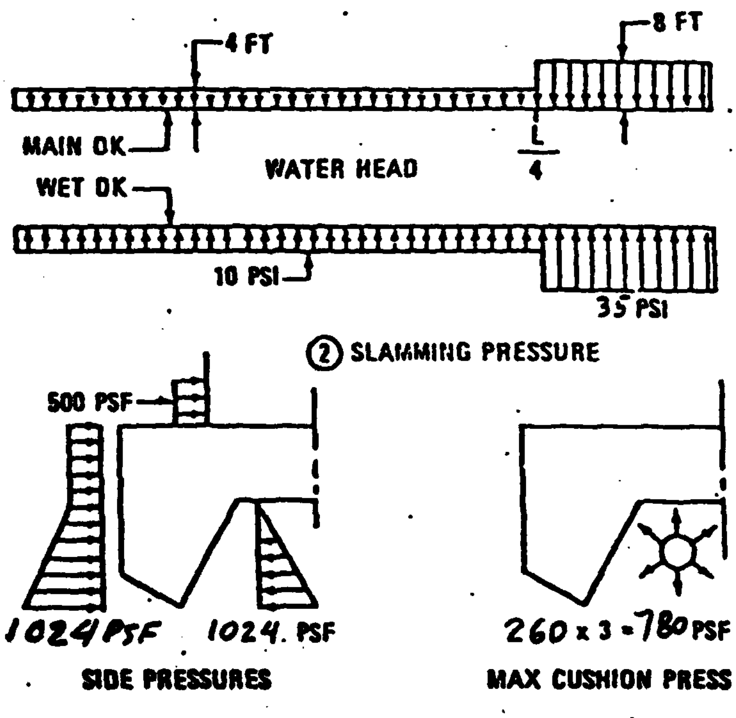
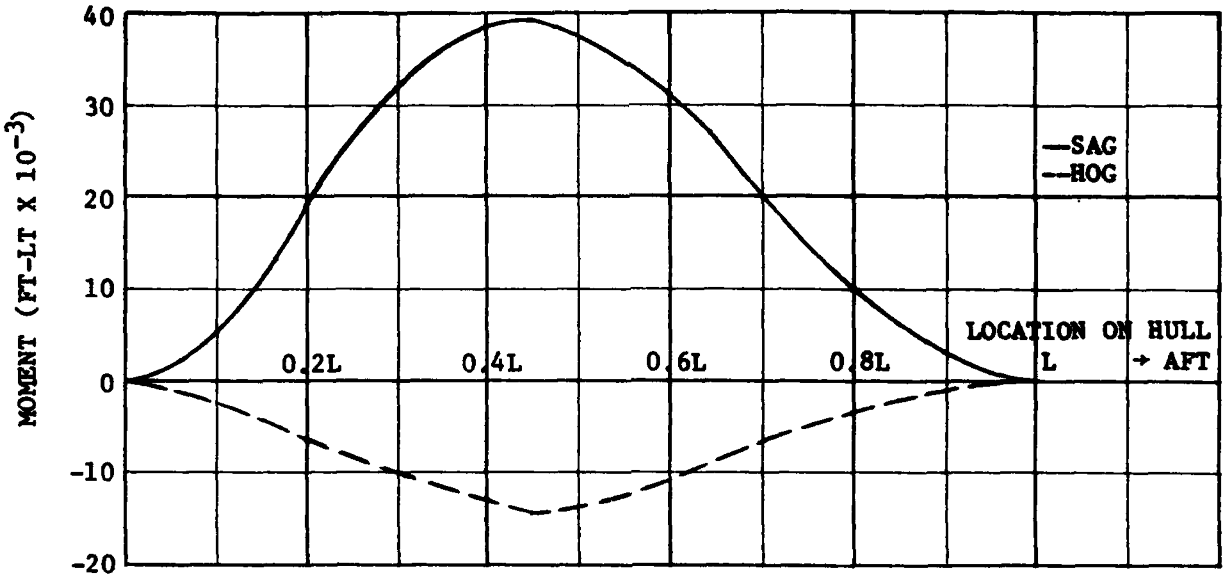
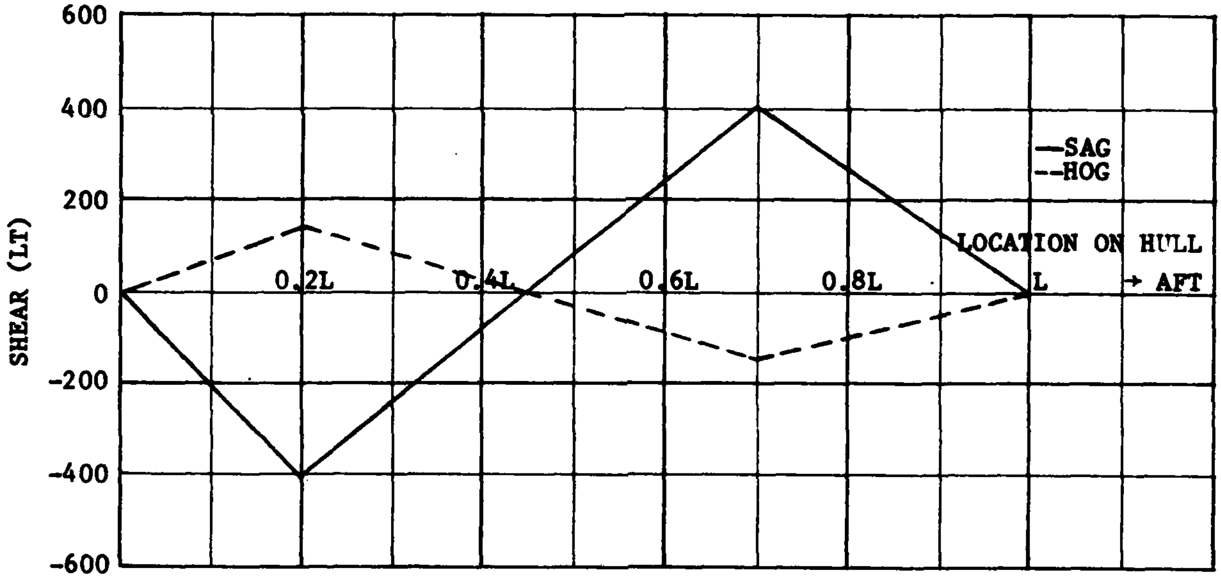


Figure 6.1-12. WLB-SES Hull Design Criteria



HULLBORNE BENDING MOMENT



HULLBORNE SHEAR

Safety Factors - SF Yield = 1.2
SF ULT = 1.5

Figure 6.1-13. WLB-SES Design Shear and Bending Moment Envelopes

SLAM PRESSURES ARE NOT COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS (OTHER THAN SLAMMING) ARE COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS INCLUDE DECK LIVE LOADS: 75 PSF (TOP OF DK HSE)
150 PSF (LIVING, OFFICE SPACES)
200 PSF (MACHINERY SPACES)

USE 60% OF SLAM PRESSURE FOR FRAME DESIGN

SAFETY FACTORS	YIELD	ULT.
HULLBORNE + LOCAL LOADS	1.2	1.5
CUSHIONBORNE + LOCAL LOADS	1.2	1.5
*SLAMMING PRESSURES	1.0	1.2

*PERMANENT SET TO A MAXIMUM OF PLATE THICKNESS IS ALLOWED

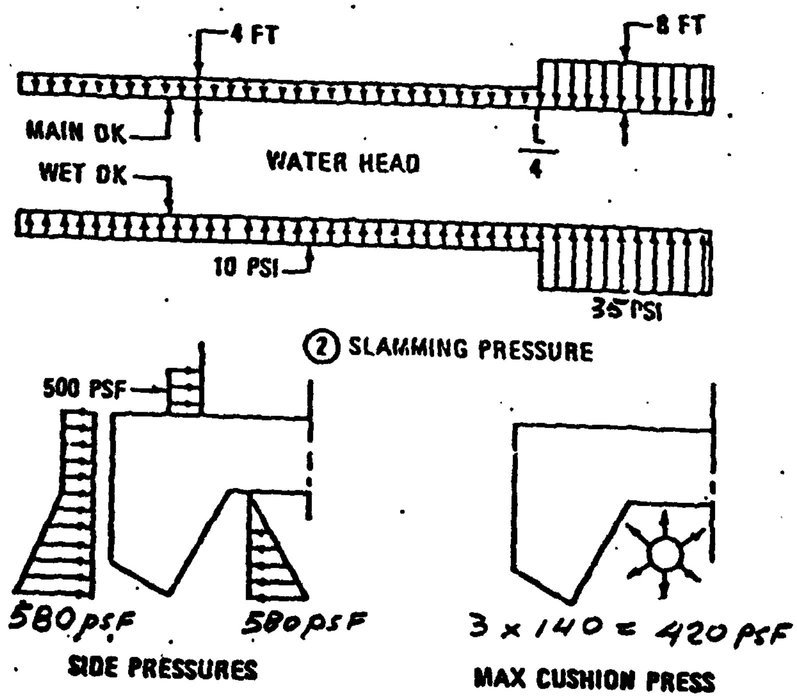
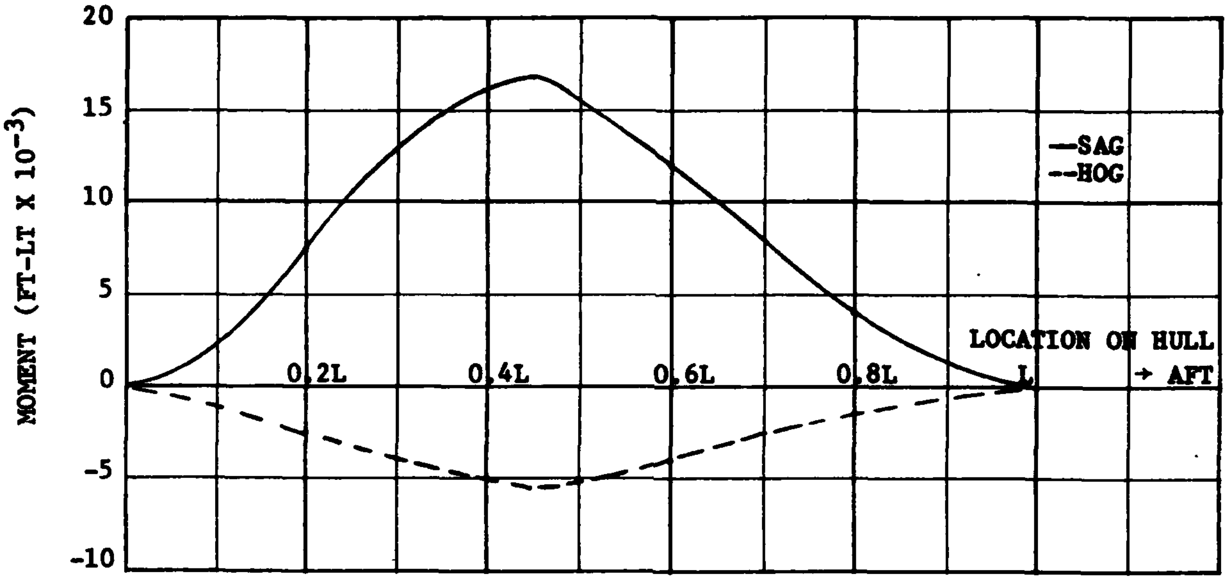
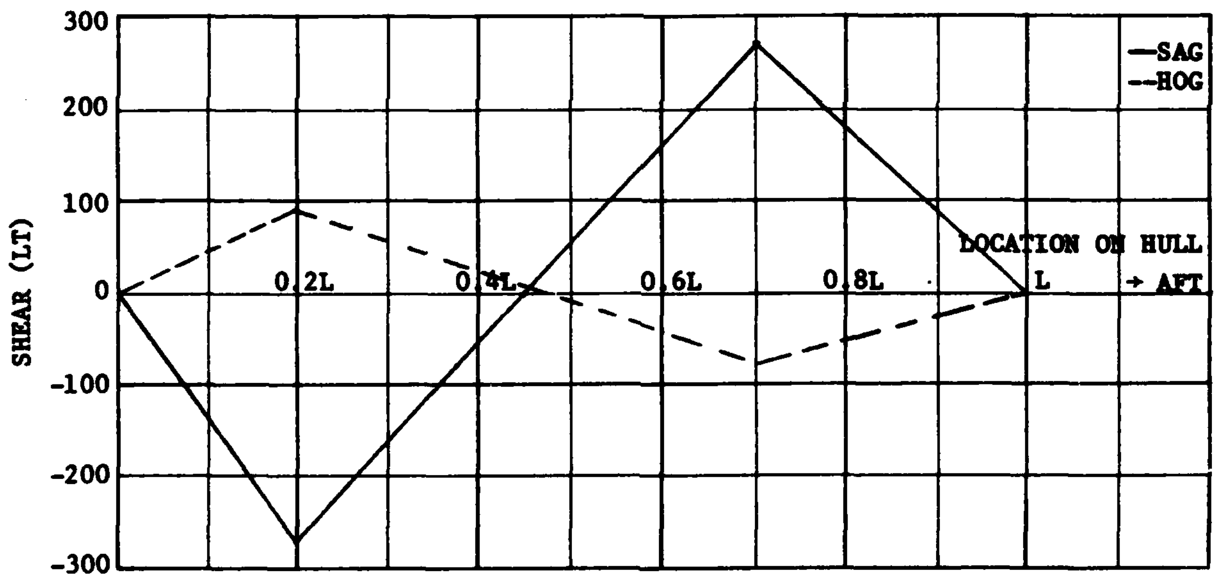


Figure 6.1-14. WPC-SES Hull Design Criteria



HULLBORNE BENDING MOMENT



HULLBORNE SHEAR

Safety Factor - SF Yield = 1.2
SF ULT = 1.5

Figure 6.1-15. WPC-SES Design Shear and Bending Moment Envelopes

Table 6.1-1. Material Allowables for 5456 Aluminum Alloy

CONDITION	PROPERTY (L DIRECTION)	MATERIAL STRENGTH (S-BASIS) (UNWELDED)	MATERIAL STRENGTH (S-BASIS) (WELDED)
H323 Sheet t < 0.188"	F_{tu}	48,000	40,000
	F_{ty}	36,000	26,000
	F_{cy}	33,000	25,000
	F_{su}	28,000	25,000
	F_{sy}	21,000	25,000
H116, Sheet and Plate 0.188" - 1.5"	F_{tu}	46,000	40,000
	F_{ty}	33,000	26,000
	F_{cy}	28,000	24,000
	F_{su}	26,000	25,000
	F_{sy}	19,000	15,000
H116 Plate 1.50" - 3.0"	F_{tu}	41,000	40,000
	F_{ty}	29,000	24,000
	F_{cy}	25,000	23,000
	F_{su}	25,000	25,000
	F_{sy}	17,000	14,000
H111 Extrusion	F_{tu}	42,000	40,000
	F_{ty}	26,000	24,000
	F_{cy}	22,000	22,000
	F_{su}	25,000	24,000
	F_{sy}	15,000	14,000

Table 6.1-2. Material Allowables High Strength Low Alloy Steel

PLATE THICKNESS	PROPERTY	MATERIAL STRENGTH LBS/SQ IN
3/16 - 5/16	F_{tu}	90,000
	F_{ty}	85,000
	F_{cu}	90,000
	F_{cy}	85,000
5/16 - 3/4	F_{tu}	90,000
	F_{ty}	80,000
	F_{cu}	90,000
	F_{cy}	80,000

NOTES:

1. ARMCO NICOP Steel.
2. No loss of strength due to welding.

The stress analysis was performed by computing element properties and shear and compression buckling allowables for plate and stiffener elements. The buckling allowables are calculated using the methods presented in DD 100-4 and stress analysis manual (AFFDL TR-69-42). Element properties and critical stresses were combined to establish crippling and column allowables. Interaction equations were used when stresses combine (i.e., compression and shear) to compute factors of safety. Minimum factors of safety were 1.5 on ultimate and 1.15 on yield.

6.1.6.1 Design Procedure -- The overall design procedure is shown in Figure 6.1-16. The basic procedure for the design of the longitudinal structure (plate and longitudinal stiffeners) is based on primary bending stress and secondary loads. The scantlings are also acceptable on the basis of a separate longitudinal primary shear stress check and transverse primary and secondary stress analysis. Transverse frame design is based on secondary load conditions but is checked for transverse primary stress in the critical center-line region. Transverse bulkhead design is based on hydrostatic damage head loading and checked for transverse primary stress at the center-line region. A separate design is performed for the composite deck grillage and deck support stanchions.

Longitudinal structure design considering primary bending and secondary loads was performed using the Design Program for Ship Structures (DPSS; formerly SSDP) Reference 6-2. DPSS provides basic longitudinal design scantlings (plates and stiffeners) which must be checked for acceptability based on primary shear stress and transverse bending stress. DPSS normally follows U.S. Navy Monohull design criteria; however, for this study, slight modifications were made in accordance with surface effect ship specifications. DPSS also provides an optimized transverse frame design based on secondary loads and a transverse bulkhead design based on damage head loads.

The design of longitudinal deep girders was performed using a mini-computer program which designs structure based on known primary and secondary loads following the same design criteria as DPSS.

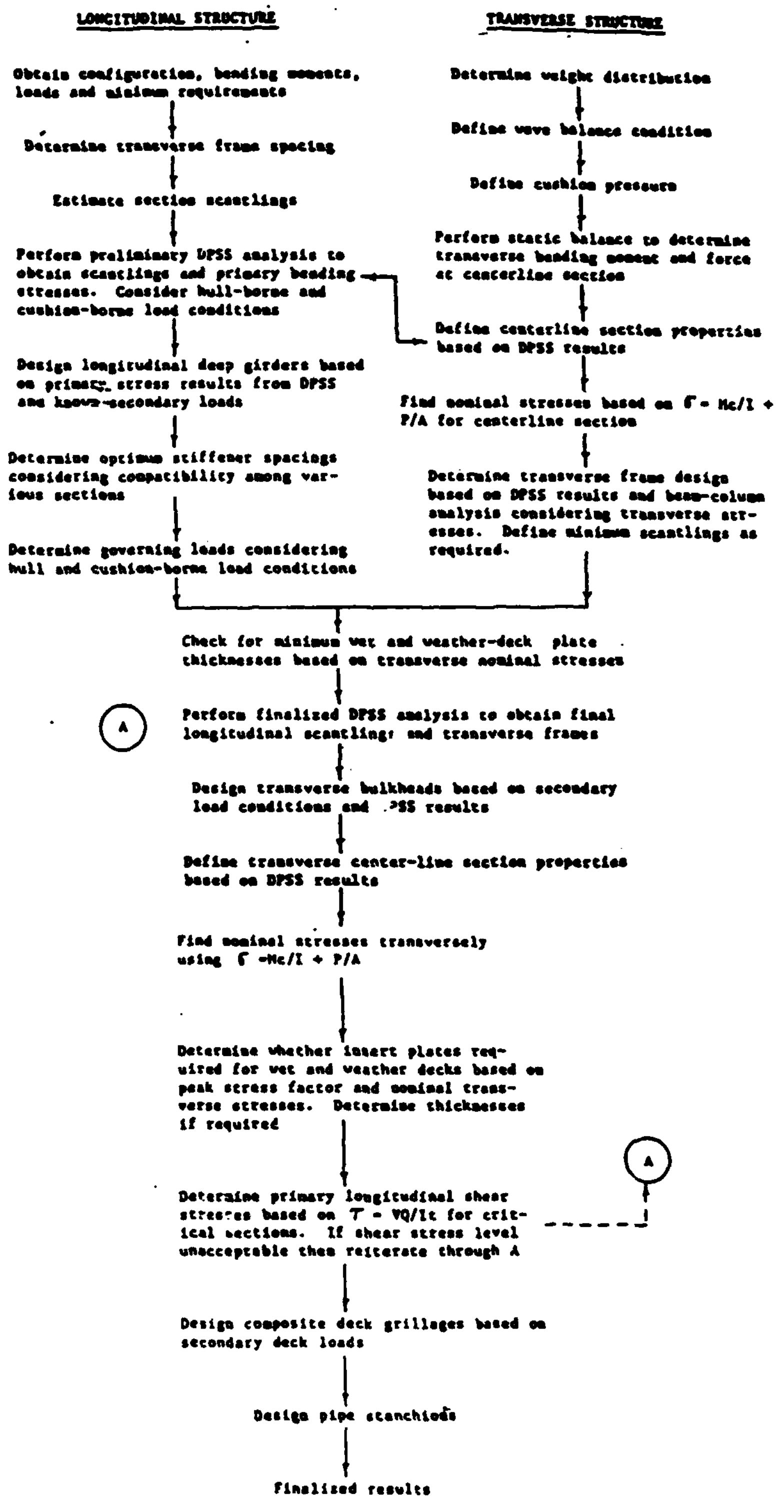


Figure 6.1-16. Structural Design Procedure

Transverse primary stresses were checked using a computer program which predicts transverse bending moment and lateral force through a static balance approach and then determines the transverse center-line section properties based on the DPSS results. Nominal transverse stresses are then determined using conventional beam theory. Peak stresses resulting from failures of linear-elastic beam theory as applied to the transverse structure are predicted based on the work of Swanek and Sikora (Reference 6-1) which accounted for peak stresses on SWATH ship structures using a finite-element approach.

The structure as designed by DPSS is checked for primary shear stress with a computer program which predicts shear stresses across the section based on $\tau = VQ/It$.

6.1.6.2 Longitudinal Structure Design — The longitudinal design process performed by DPSS is described in detail in Reference 6-2. The design process is based on providing sufficient material to meet or exceed minimum accepted strength and stability criteria for a predicted range of load conditions. The criteria are met through the use of safety factor equations which ensure a minimum degree of conservatism. The safety factor equations which form the basis of the DPSS design process are briefly listed as follows:

1) Factor of safety for plate buckling:

$$F.S. = \frac{F_{pc}}{\sigma_1 + \sigma_2} \geq 1.00$$

where σ_1 = compressive primary bending stress

σ_2 = maximum secondary bending stress due to normal load

F_{pc} = plate panel buckling strength

2) Factor of safety for ultimate buckling of plate-stiffener panel

$$F.S. = \frac{F_u \times (F_c/F_y)}{\sigma_1 + \sigma_2} \geq 1.50$$

where F_{du} = ultimate compressive strengty of plate panel

F_y = yield strength

F_c = allowable column strength for plate-stiffener combination

3) Factor of safety for beam/column interaction

$$F.S. = \frac{1}{\frac{1.25_1}{F_c} + \frac{1.25_2}{F_y}} \quad 1.00$$

4) Factor of safety for tension

$$F.S. = \frac{F_y}{\sigma_1 + \sigma_2} \geq 1.20$$

5) Factor of safety for shear

$$F.S. = \frac{F_y}{\tau_2} \geq 2.00$$

where τ_2 = maximum secondary shear stress due to normal load

6) Factor of safety for lateral stability of stiffener

$$F.S. = L_s \,/\, L \geq 1.00$$

where L = span length of stiffener

L_s = maximum stable length of tee stiffener without supports

Note: These equations have been transformed from those listed in Reference 6-2 to reflect absolute factors of safety with respect to buckling or yield stress for purposes of consistency with the project specifications.

6.1.6.3 Transverse Analysis -- A transverse primary stress analysis was performed at the critical centerline section for the plating and transverse frames designed by DPSS. This analysis was performed to determine the adequacy of the plating and transverse frames provided by DPSS based on predicted transverse primary loads.

Transverse primary bending moment and lateral force due to cushion pressure at thecenter-line section were predicted as part of this study basedon a computerized static balance approach. This approach considered hullborne and cushionborne states for both stillwater and wave balance conditions. Based on this work, the cushionborne balance with an overload pressure of 1200 psf produced the most extreme load condition. In order to balance the ship with this extreme overload pressure, an acceleration factor was applied to the known ship weight distribution.

Primary bending stresses based on these predicted loads and the known plate and transverse frame design obtained from DPSS were obtained. However, finite-element studies performed by Swanek and Sikora (Reference 6-1) for SWATH-type hull structures have indicated that conventional nominal stress calculations based on the assumption of plane sections remaining plane are inadequate for the transverse stress analysis of twin-hulled ships. Specifically, shear lag effects lead to increased stresses in the region of transverse bulkheads and reduced stresses at mid-bay regions. This effect is illustrated in Figure 6.1-17. In order to verify that these effects occur for the 2100 ton WHEC-SES, a simplified finite element analysis was performed for the midship section based on the predicted transverse loads and the plating and transverse frame design obtained using DPSS. The results of this study, shown in Figure 6.1-18 verify that these shear lag effect are significant for the SES-type ship and require consideration. Equations based on the work of Swanek and Sikora were obtained to estimate the magnitude of peak stresses in the region of the transverse bulkheads. These stress predictions are based on known hull geometry and calculated nominal stresses based on $\sigma = Mc/I + P/A$. These equations are listed in Table 6.1-3. To reduce the magnitude of these peak stresses when critically

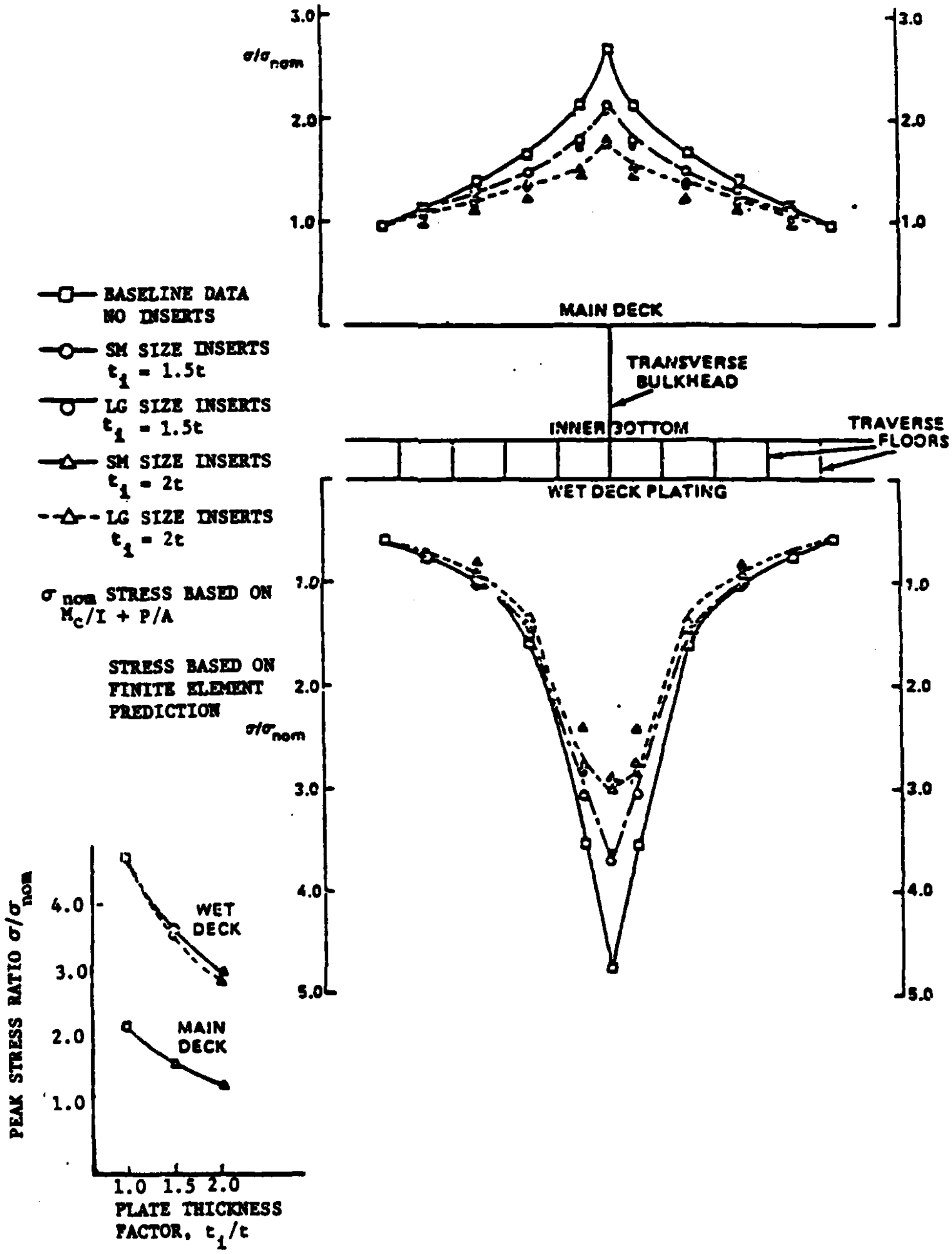


Figure 6.1-17. Finite Element Based Estimate of Shear Lag Peak Stresses for Transverse Loading of SWATH Hull Structure

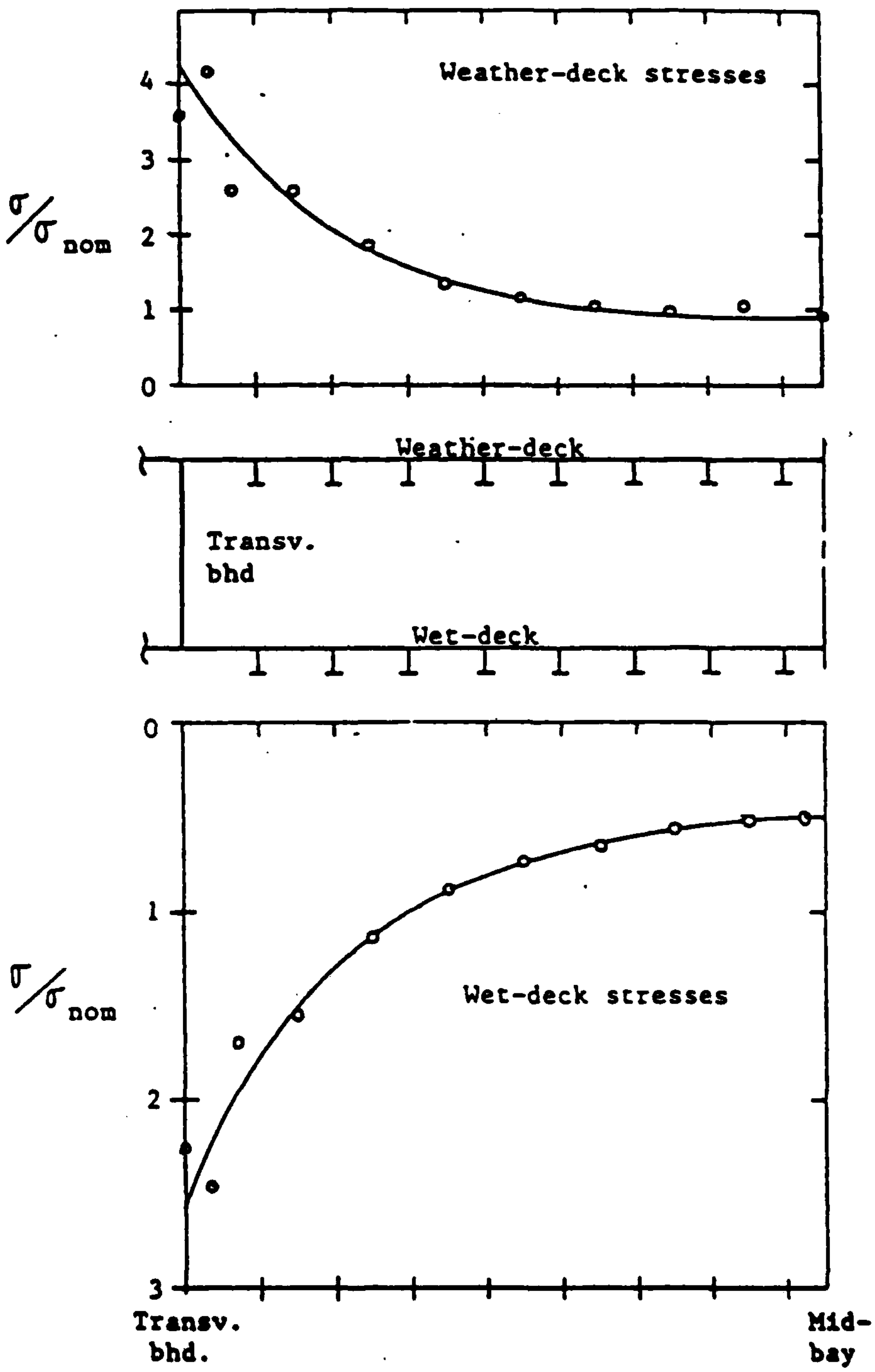


Figure 6.1-18. Approximate Midship Transverse Primary Stress Distribution Based on Finite-Element (NASTRAN) Analysis for 2100 Ton SES

Table 6.1-3. Equations for Estimation of Peak Stresses to Lag Effects*

$$\sigma = \sigma_{nom} \times f \qquad \text{where } \sigma_{nom} = Mc/I + P/A$$

Peak stress factor, f:

<u>No insert plates</u> (see figure 14)

for weather deck; $f = 1.2 \times (0.831 + 2.803 \times S / B)$

for wet deck; $f = 1.2 \times (1.829 + 6.114 \times S / B)$

<u>With insert plates</u>

for weather deck; $f = 1.2 \times (0.831 + 2.803 \times S / B) \times (1.96 - 0.96 \times t/t_o)$

for wet deck; $f = 1.2 \times (1.829 + 6.114 \times S / B) \times (1.96 - 0.96 \times t/t_o)$

where S = transverse bulkhead spacing
B = breadth of ship
t = base plate thickness
t_o = insert plate thickness

*Note: These equations were derived for SWATH hull structure and involve an unknown uncertainty as applied to SES structure; therefore, an assumed uncertainty factor of 1.2 is included with these equations.

high, insert plates were designed for the transverse bulkhead regions as shown in Figure 6.1-19. Insert plate design was based on the equations listed in Table 6.1-3. Transverse structural adequacy was based on the same criteria applied to the longitudinal structure.

6.1.6.4 Shear Stress Analysis — Primary shear stress is not considered in the DPSS design procedure. In order to determine the nature of the shear stresses resulting from the known shear forces provided with the model test results, a separate analysis was performed for each of the sections modeled with DPSS. The shear stress determination was based on the equation $\tau = VQ/It$ and has been computerized in order to obtain the complete shear stress distribution across the transverse section. A typical shear stress plot resulting from this analysis has been included in Figure 6.1-20.

6.2 PROPULSION AND LIFT SYSTEMS

In selecting components for propulsion and lift systems, emphasis was placed on equipment in current production and the objectives for low cost and minimum lead times for fabricated hardware. Preliminary performance analysis was accomplished to provide limited parametic data for the purposes of selecting propulsion prime movers and the determination of airflow requirements for the lift system. The study addressed the following major elements of propulsion and lift systems.

- Propulsion Engines
- Propulsors
- Lift Engines
- Lift Fans
- Ride Control System
- Bow and Stern Seals

6.2.1 PROPULSION ENGINES — Propulsion engines were selected from gas turbine and high speed marine diesel engines currently in production and readily available. Gas turbine options were constrained to engines produced by U.S. manufacturers. However, diesel engine candidates were selected from

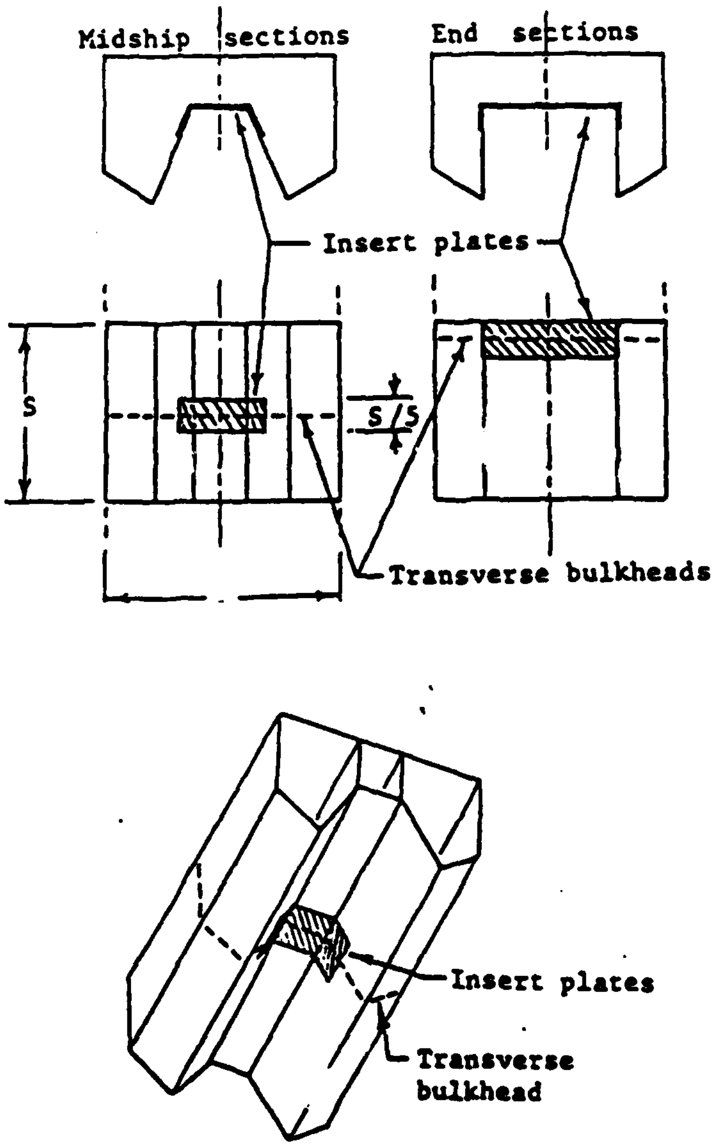


Figure 6.1-19. Illustration of Insert Plates

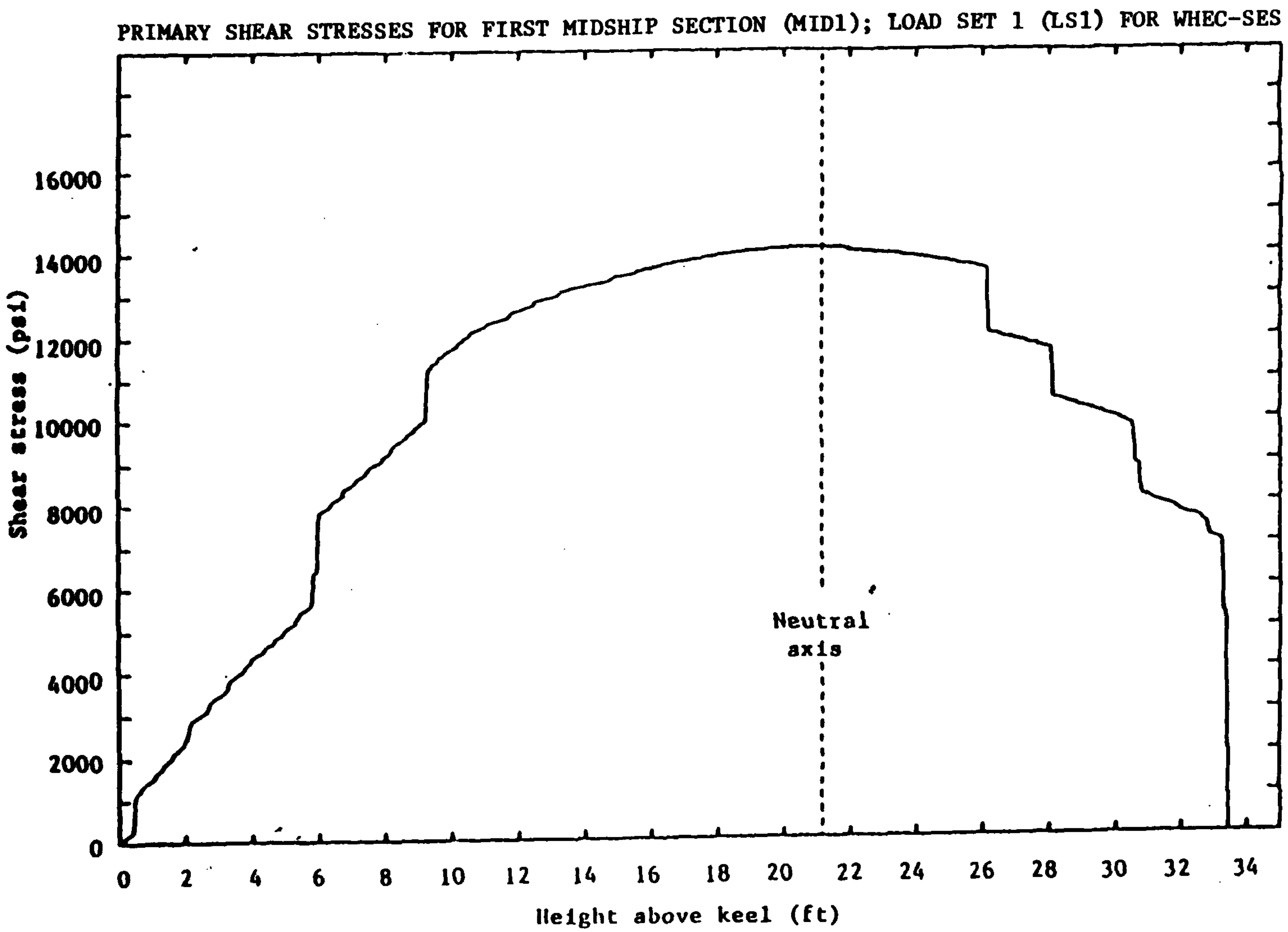


Figure 6.1-20. Typical Primary Shear Stresses for WHEC-SES

high speed engines obtainable from European sources in that domestically produced diesel engines of comparable ratings are significantly heavier.

The gas turbine engines considered together with both the present and projected power ratings are listed in Table 6.2-1. The diesel engine candidates are listed in Table 6.2.2.

It should be noted that the diesel engines identified in Table 6.2-2 were selected to be representative of the types of high speed diesel engines presently available. Competitive engines are available also from S.E.M.T. Pielstick of Saint Davis, France and M.A.N. of Nurenberg, Germany.

On the basis of the power requirements derived through preliminary performance analysis of each design concept, propulsion engines were selected as shown in Table 6.2-3.

The selection of gas turbine prime movers for the WHEC was driven by the power level requirements. However, the operational requirements for the craft entail the need for high operating efficiency under both high (cushionborne) speeds and low speed (cushionborne and hullborne) conditions. In order to satisfy this requirement a CODOG type propulsion plant was selected in which two of the diesel lift engines can be used to provide propulsive power when the craft is operating in the low speed mode. This system provides the high power density of the gas turbine to satisfy the power requirements for high speed operation and the advantages of the low specific fuel consumption of diesel engines for low speed cruise. The selected plant utilizes separate propulsion and lift systems for high speed operation on-cushion. For low speed operations the main propulsion engines are shut down and the aft lift system prime movers are used for propulsion. The essential features of the WHEC propulsion system are shown in Figure 6.2-1. As shown in Figure 6.2-1 the aft lift diesel engine provides power through the propulsion gearbox. Clutches provide the capability for either the gas turbine or diesel power to the propeller. A clutch is also provided to decouple the lift fans from the power train for hullborne operation on the diesel engine.

Table 6.2-1. Propulsion Gas Turbine Options

ENGINE	MCP [1]	GROWTH MCP [1]	MIP [1]	WEIGHT [2] (lb)	SFC- $\frac{lb}{hp\text{-}hr}$
LM500	5,400	-	6,000	2,292	0.46
570KF	5,833	6,500	6,300	1,990	0.47
TF40	3,528	-	4,248	1,636	0.53
501KF	3,940	-	4,340	2,616	0.51
GRPF990	5,000	-	5,500	5,100	0.50
LM2500	24,000	27,000	27,000	10,500	0.40

1. 80°F Standard day.
   4" H_2O and 6" H_2O inlet and exhaust losses respectively.
   MCP - Maximum Continuous Power
   MIP - Maximum Intermittent Power
   SFC - Specific Fuel Consumption
2. Basic engine plus inlet, exhaust, and controls.

Table 6.2-2. Diesel Engine Options

ENGINE	MCP	MIP	WEIGHT (lb)	SFC- $\frac{lb}{hp\text{-}hr}$
MTU 8V331TC92	885	1,065	5,082	-
MTU12V396TB93	1,630	1,960	7,854	.350
MTU16V538TB91	3,060	3,660	14,883	.375
MTU20V538TB92	4,265	5,100	19,474	.388
MTU20V956TB92	5,535	6,660	35,765	.373
SACM12V195RVR	2,700	3,260	15,766	.352
SACM16V195RVR	3,600	4,320	21,560	.350
SACM20V240RVR	7,000	8,400	46,084	.344
SACM20V195RVR	4,500	5,400	24,696	.352
WM400T	503	550	2,822	.366

Table 6.2-3. Propulsion Plant Selection

CONCEPT	PROPULSION POWER REQUIRED (SHP)	SELECTED PRIME MOVER	POWER PROVIDED (SHP)
WHEC	34,000	***Two LM-2500 Gas Turbines	48,000 MCP 54,000 MIP
WMEC	14,000	****Two SACM 20V240RVR Diesel Engines	14,000 MCP 16,800 MIP
WLB	5,400 + 1,800 = 7,200	*Two SACM 16V195RVR Diesel Engines	7,200 MCP 8,640 MIP
WPC	4,900 + 500 = 5,400	**Two SACM 12V195RVR Diesel Engines	5,400 MCP 6,520 MIP

* 1800 SHP for integrated lift fans included.
** 500 SHP for integrated lift fans included.
***Two aft lift system engines provide CODOG low-speed cruise propulsion.
****Two aft lift system engines provide CODOD low-speed propulsion.

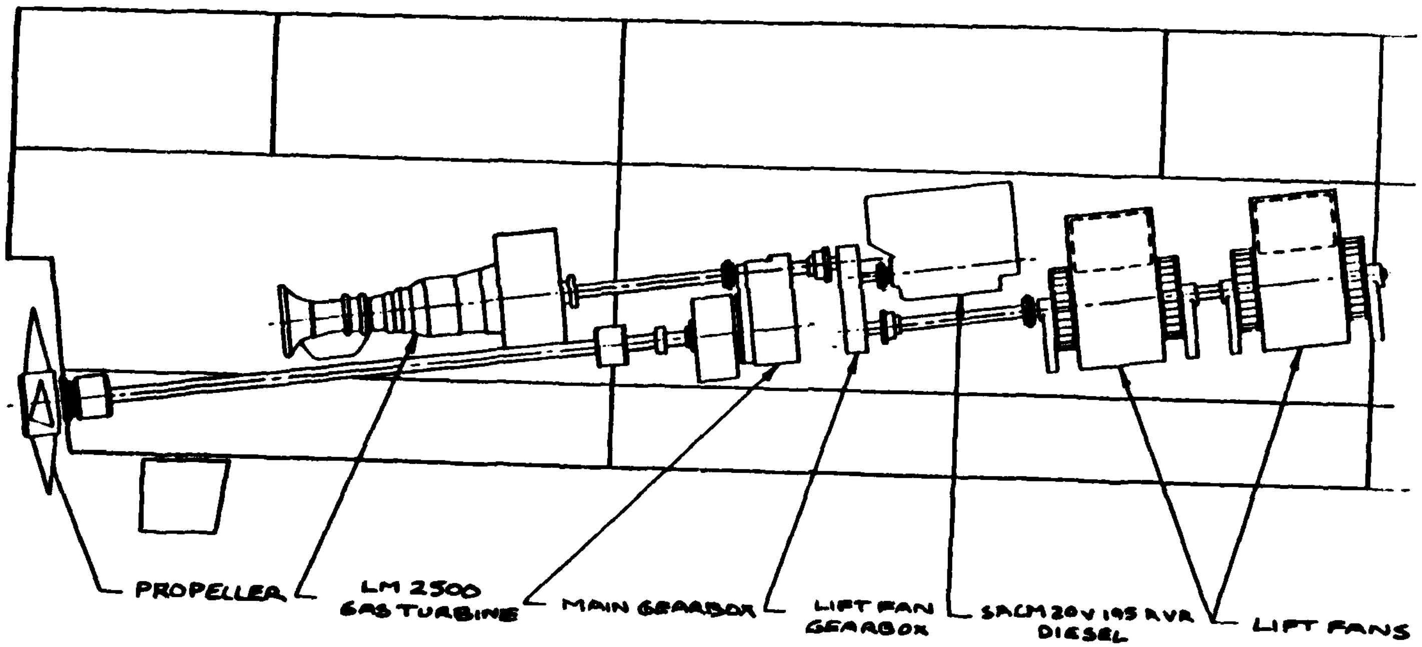


Figure 6.2-1. WHEC Propulsion Machinery Arrangement

For the other ship concepts the propulsion power requirements were within the range of readily available high speed marine diesel engines and therefore engines from this group were selected.

6.2.2 PROPULSORS -- Propeller type propulsors were established as the desired propulsion approach at the outset of the study. Avoidance of cavitation, and the associated performance loss was the major consideration in propeller design selection. Standard propeller series data for the "Gawn-Burrill", Wagenigen B" and "Newton-Rader" propeller types were examined. For propeller sizing, the "Newton-Rader" data were used in that this propeller offers a high efficiency and the data include information above and below the cavitation index of the USCG propeller installations.

The "Newton-Rader propeller performance charts are presented in Figures 6.2-2 and 6.2-3. It is noted that propeller shaft inclination influences propeller performance and that at small shaft angles, a small gain in the basic propeller performance may be anticipated. However, this gain was not assumed in the performance analyses relative to this study It should be noted that propellers offering performance characteristics comparable with the Newton-Rader type are readily available from the Michigan Wheel Company.

An in-depth, optimized hydrodynamic design of the propeller was not included within the scope of this effort. However, subsequent optimization changes should have little effect on the design selections made within this study.

6.2.3 LIFT ENGINES -- Diesel engines were chosen for driving the lift fans. Fuel efficiency and ready availability of marinized diesels in a broad range of power levels were the major considerations in this decision. Selections for the applications in this study were made from the SACM and MTU lines of high speed marine diesel engines. The candidate lift engines are included in Table 6.2-2. The lift engines selected for each of the design concepts are listed in Table 6.2-4.

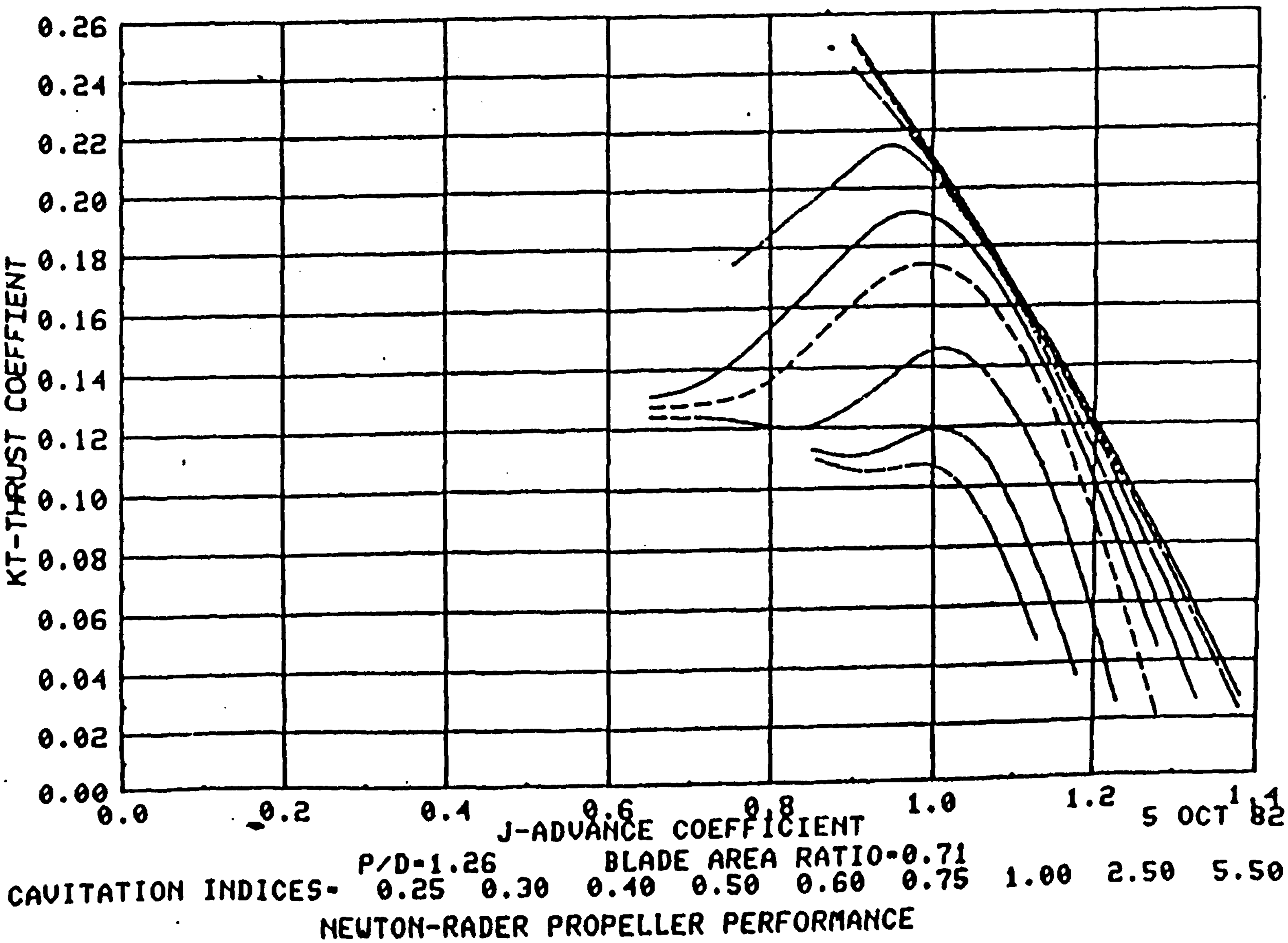


Figure 6.2-2. Propeller Thrust Coefficient

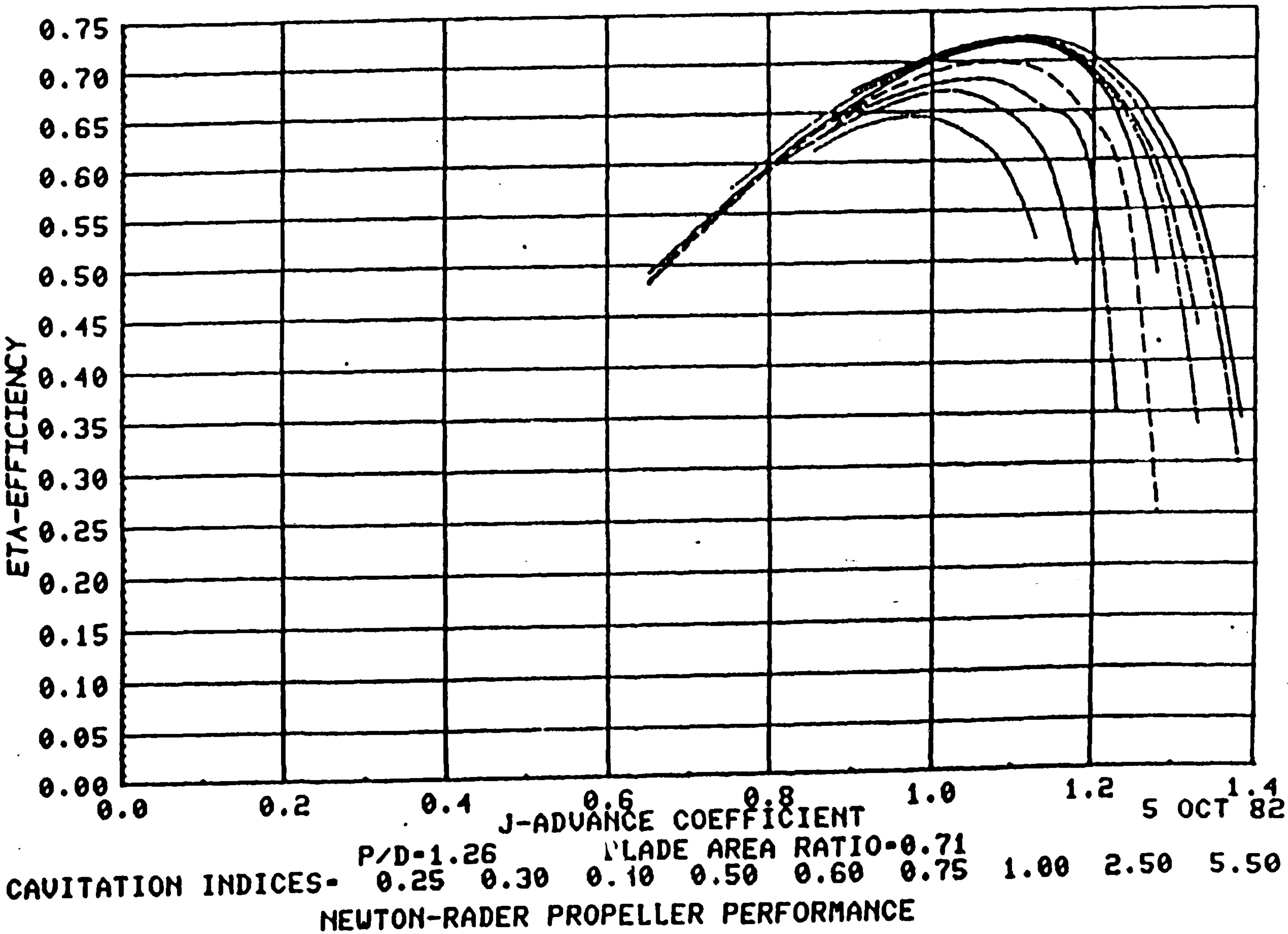


Figure 6.2-3. Propeller Efficiency

Table 6.2-4. Lift Engine Selection

SHIP CONCEPT	LIFT POWER REQUIRED (SHP)	LIFT ENGINE SELECTED	LIFT POWER PROVIDED (SHP)
WHEC	7,000	** Four SACM 20V195RVR Diesel Engines	18,000 MCP 21,600 MIP
WMEC	4,000	***Three MTU 12V396TB93 Diesel Engines	4,890 MCP 5,880 MIP
WLB	1,700 + 1,800* = 3,500	Two MTU 8V331TC92 Diesel Engines	1,770 MCP 2,130 MIP
WPC	1,000 + 500* = 1,500	Two Wizeman Marine (Mercedes-Benz) WM400T Diesel Engines	1,006 MCP 1,100 MIP

* 1800 SHP lift power comes from diesel propulsion engines (WLB).
500 SHP lift power comes from diesel propulsion engines (WPC).

** Two aft lift system engines provide CODOG low-speed cruise propulsion.

*** Two aft lift system engines provide CODOD low-speed cruise propulsion.

6.2.4 LIFT FANS -- The mixed flow rotating-diffuser type lift fan was selected for all USCG SES Designs on the basis of the superior performance demonstrated by this fan in Navy test programs. This is essentially a combined axial inlet and centrifugal outlet type with the shroud and back-plate extended radially beyond the blade tips to provide a diffusing passage which is integral with the rotating assembly. This type fan has demonstrated good efficiency (in excess of 0.84) and a high measure of tolerance for the pressure fluctuations which occur in the surface effect ship air cushion. The rotating diffusor provides a very quiet fan.

6.2.5 RIDE CONTROL SYSTEM -- For minimum drag, an SES should ride as high out of the water as possible. Hence, a considerable flow of air is continuously being forced into the cushion by the lift fans to make up for leakage at the waterline. This flow can be controlled to minimize the vertical motion. Vertical motion is near minimum when cushion pressure is held constant thus vertical motion can be controlled by rapid manipulation of flow to minimize the cushion pressure variation which normally results from wave action. This can be done either by Fan Flow Control (FFC) by means such as cushion inlet guide vanes (IGV's) or by releasing air through a fast response vent valve - Vent Valve Control (VVC), or ride control can be accomplished by a combination of both systems. The modulation of the vent valves and IGV's is performed in response to commands from a closed loop type ride control system (RCS) which senses the cushion pressure and modulates the air flow to minimize pressure variations and hence the vertical accelerations of the craft.

These ride control devices were demonstrated to be effective during the 3KSES program. The methods were refined over the past ten years at the Surface Effect Ship Test Facility (SESTF) in sea trials using the SES-100A, SES-100B and XR-1D testcraft. From this test and development activity it has been determined that the electronics and operator control functions of an RCS system can be made to a great extent universal: that is, one system can be made flexible enough to meet the signal handling needs of a wide variety of ship configurations. Procedures for adjusting the system to a specific ship are well established as a result of the XR-1D work.

For the USCG ship designs, both variable flow fans and vent valves were selected for ride control in that this approach offered the advantages of lower lift power and maximum state-of-the-art performance. The selected variable flow fan design is based upon that tested by Aerophysics Company for the U.S. Navy; the results of this test are contained in Reference 5-8. The cushion vent valves are similar to those installed on the SES-200 which is currently in U.S. Navy service.

The RCS can be implemented as an analog or a digital system. The XR1-D system was analog. The recommendation of the SESTF development program called for a digital system. This has attractive prospects for interfacing with an integrated lift system control wherein the parameters for ride control are permanently stored and can be readily modified. A functional diagram of a typical integrated lift and ride system is shown in Figure 6.2-4.

6.2.6 BOW AND STERN SEALS -- A Transversely Stiffened Membrane (TSM) bow seal and a multi-loop type stern seal were selected for each of the four ship concepts. These seals are constructed from state-of-the-art elastomeric and fabric materials and are the result of the SES seals development accomplished by the Navy over the last ten years.

6.2.6.1 Bow Seal -- The Transversely Stiffened Membrane (TSM) type bow seal was selected for the USCG ship designs in view of the excellent performance this seal has demonstrated in the U.S. Navy XR-1 surface effect testcraft.

The general construction of the TSM bow is shown in Figure 6.2-5. As shown in Figure 6.2-5, the seal structure in contact with the water surface is a flexible material made of rubber-impregnated nylon cloth. The contact area incorporates plastic (GRP) battens to reduce the wear caused by flagellation. This lower section of the TSM seal, called the parasol, consists of a series of horizontal loops of flexible seal material which are joined together to form a face in the shape of a circular arc. The ends of

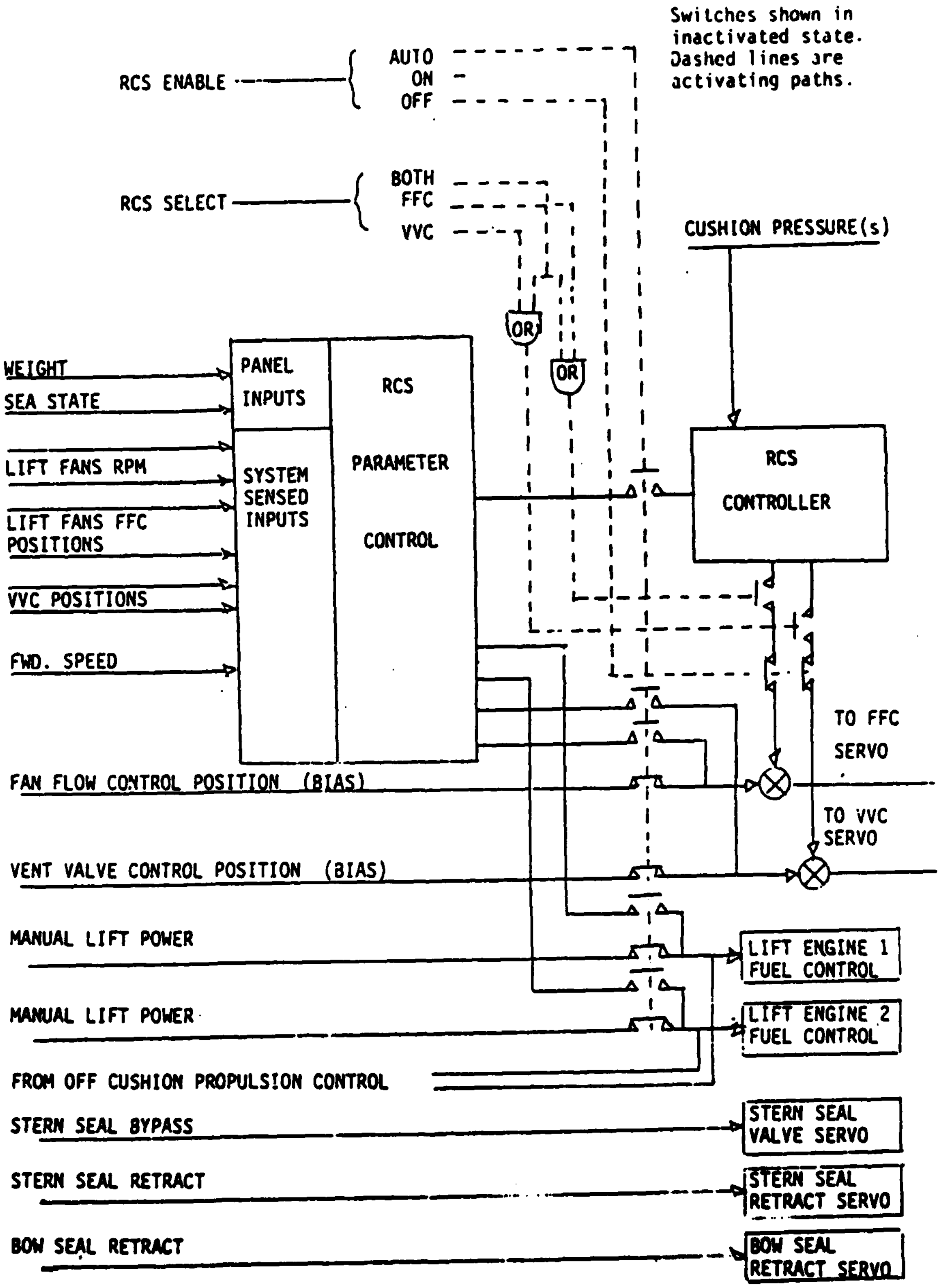


Figure 6.2-4. Integrated Lift and Ride Control System

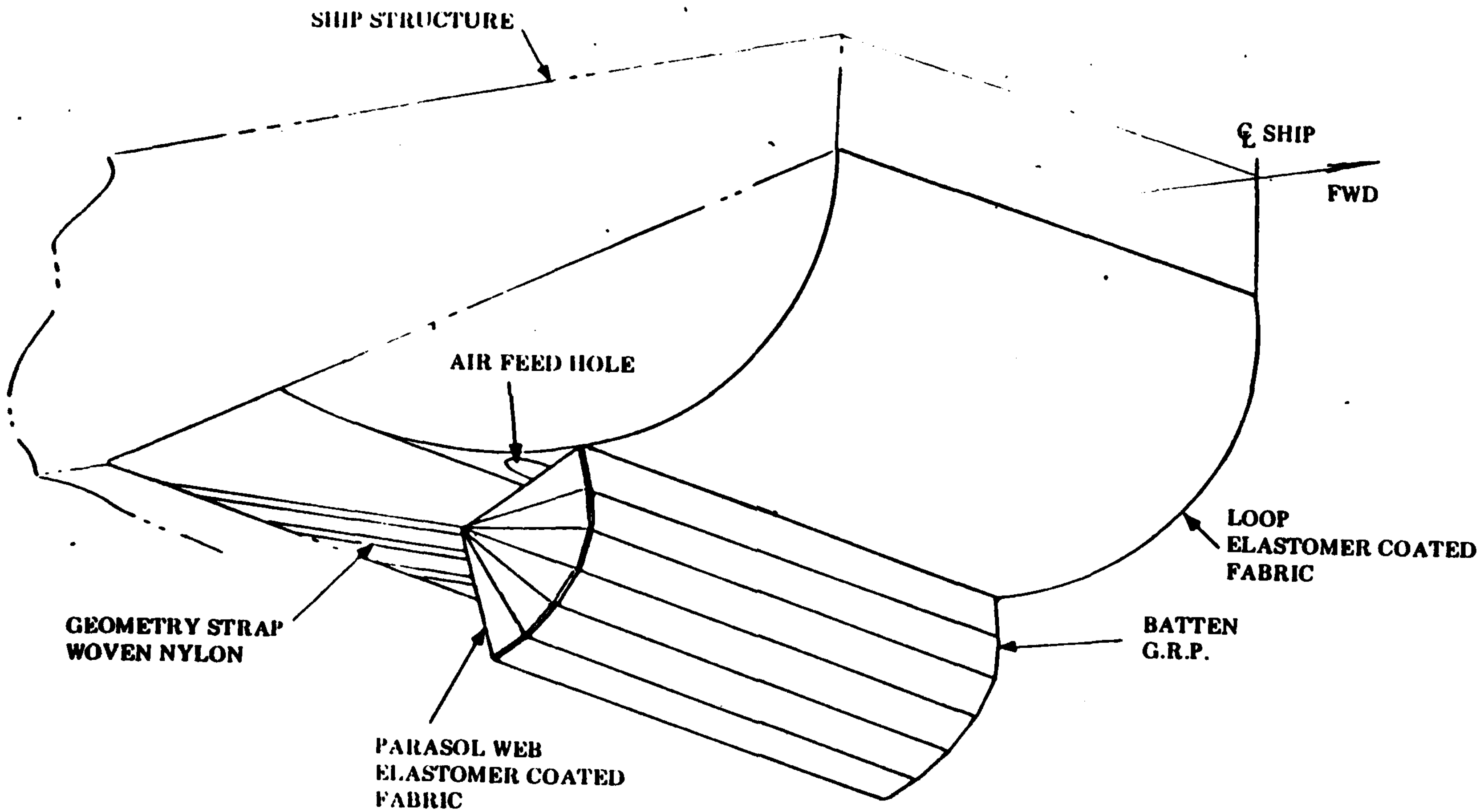


Figure 6.2-5. Transverse Stiffened Membrane Bow Seal Assembly

these loops are connected together along a common horizontal line aft of the parasol face and then joined to a series of geometry straps or cables which attach to the wet deck. The transverse battens are attached to the inside of the loops along the parasol face in order to maintain the overall shape of the parasol. The battens are bonded to the loop material to maintain intimate contact for resistance to flagellation. Since these transverse battens are short in the arc direction and are fully supported by the panel webs, the resulting stresses are low and almost unidirectional. The joints between the panel loops are flexible, and allow the seal to conform to the water surface as the waves pass through to the cushion. The number of parasol loops may be varied in order to maintain the stress level within the material capabilities. The face of the parasol is covered by an additional sacraficial sheet of seal material to provide a smooth surface in actual contact with the water and to protect the panel loop junctions.

The parasol is attached to the seal bag at the junction of the inner and outer bag loops. The aft end of the inner loop attaches to the wet deck forward of the geometry strap attachment while the forward end of the outer loop attaches to the wet deck towards the bow. Retraction cables connect form the bag/parasol junction to the retraction mechanism on the wet deck. This retraction mechanism provides for optimum seal settings during partial cushion operation and for seal retraction during hullborne operations. A single or multiple loop outer seal bag is used in order to maintain the pressure forces and loads within the limits of available materials. When multiple loop bags are used, geometry straps connect between the loop junctions and the seal deck. Air flow orifices in the inner loop at a location close to the parasol/bag junction allow seal bag air to flow into the cushion, maintain a positive pressure ratio between the seal bag and the cushion and provide a path for any water entrapped in the bag to flow out. The positive pressure in the seal bag provides stability for the seal in the event of cushion venting as well as a pitch restoring force.

The two-dimensional TSM seal is essentially contained within the sidehulls which reduces the transverse loads on any material joints. both the parasol and the outer bag loop have end caps in order to provide for good air closure along the sidehulls/seal interface. The parasol is designed to remain within the sidehulls under all operating conditions. The TSM seal geometry is based on force and moment balances when the seal is in the fully deployed position and with nominal pressures. Should the seal position be altered by wave or motion forces, the seal returns to the nominal position when the disturbing forces are removed in order for the forces and moments to return to the balanced state.

6.2.6.2 Stern Seal -- The stern seal, as shown in Figure 6.2-6 consists of three loop bellow bags, fabricated from state-of-the-art elastomeric materials. The three loops are interchangeable and attach to support cables through a series of node points on a terminating catenary arrangement for each loop. From the node points on the bag, the cables attach to a common wet deck fitting which maintains the bags' inflated geometry. The retraction mechanism consists of a series of straps, each of which passes around the bag and ends on a transverse rotating shaft which is capable of retracting the seal.

6.2.6.3 Seal Structures -- The seal structures were developed relative to the seal size and cushion pressure for each of the U.S.C.G. SES designs. The results are summarized as follows:

WHEC - SES	-	Table 6.2-5
WMEC - SES	-	Table 6.2-6
WLB & WPC - SES	-	Table 6.2-7

Attachment fittings are fabricated from corrosion resistant metal. The mounting points for fittings are reinforced by backup members in order to transfer the loads into the primary ship structure. Rotating connections are designed to obviate supplemental lubrication. Dissimilar metals, faying surfaces, and fastener holes are suitably protected with faying surface sealants to prevent galvanic corrosion.

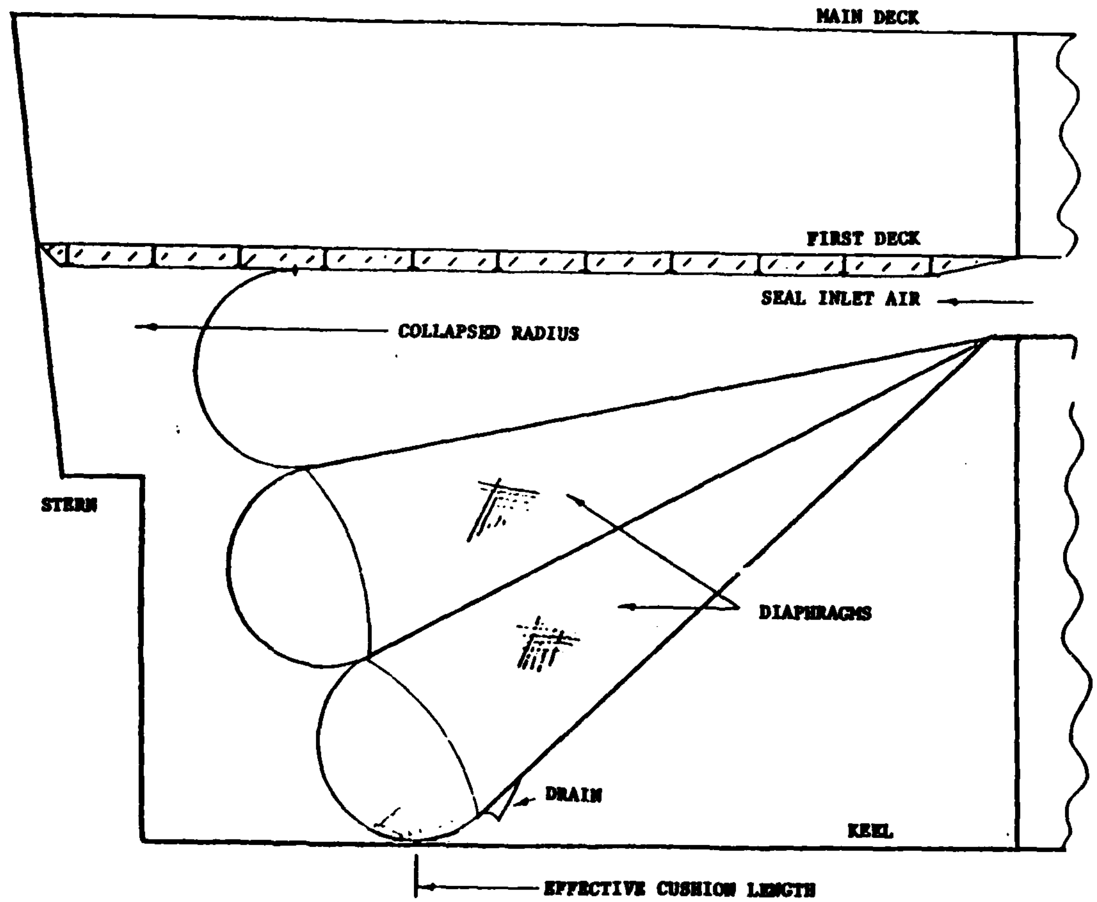


Figure 6.2-6. Multi-Loop Stern Seal - Typical Features

Table 6.2-5. Seal Materials for WHEC-SES

MATERIAL CHARACTERISTIC	BAG		PARASOL (NOTE (1))
	BOW	STERN	
Fabric Type	Nylon 3x3 (Basket Weave)	Nylon 3x3 (Basket Weave)	Nylon 3x3 (Basket Weave)
Coating Type	Neoprene Base Rubber	Neoprene Base Rubber	Neoprene Base Rubber
Material Weight	170 Oz/Yd^2	90 Oz/Yd^2	90 Oz/Yd^2
Tensile Strength { Warp	3000 pli	1240 pli	1240 pli
Tensile Strength { Fill	3000 pli	1280 pli	1280 pli
Minimum Tear Strength	>500 pli	>500 pli	>500 pli

Note:

1. Parasol stiffening elements (battens) have the following dimensions:

   Thickness = 3/16 to 1/4 In.

   Width = 1 In. - 1-1/2 In.

   Length ≈ 18 In.

   Batten material is fiber reinforced plastic (Scotchply 1002) with fibers parallel to the long (18 In.) side of the batten.

2. See WPC-SES for batten material properties.

Table 6.2-6. Seal Materials for WMEC-SES

MATERIAL CHARACTERISTIC	BAG		PARASOL (NOTE (1))
	BOW	STERN	
Fabric Type	Nylon 3x3 (Basket Weave)	Nylon 3x3 (Basket Weave)	Nylon 3x3 (Basket Weave)
Coating Type	Neoprene Base Rubber	Neoprene Base Rubber	Neoprene Base Rubber
Material Weight	170 Oz/Yd^2	90 Oz/Yd^2	90 Oz
Tensile Strength — Warp	2400 ply	1240 ply	1240 ply
Tensile Strength — Fill	2400 ply	1280 ply	1280 ply
Minimum Tear Strength	>500 ply	>500 ply	>500 ply

Note:

1. Parasol stiffening elements (battens) have the following dimensions:

   Thickness = 1/8 to 3/16 In.

   Width = 1 In. - 1-1/2 In.

   Length ≈ 14 In.

   Batten material is fiber reinforced plastic (Scotchply 1002) with fibers parallel to the long side of the batten.

2. See WPC-SES for batten material properties.

Table 6.2-7. Seal Materials for WLB and WPC-SES

MATERIAL CHARACTERISTICS	BAG		PARASOL (NOTE (1))
	BOW	STERN	
Fabric Type	Nylon 3x4 (Basket Weave)	Nylon 3x4 (Basket Weave)	Nylon 3x4 (Basket Weave)
Coating Type (2)	Neoprene Base Rubber	Neoprene Base Rubber	Neoprene Base Rubber
Material Weight	90 Oz/Yd^2	90 Oz/Yd^2	90 Oz/Yd^2
Tensile Strength — Warp	1200 ply	1200 ply	1200 ply
Tensile Strength — Fill	1200 ply	1200 ply	1200 ply
Tear Strength	200 ply	200 ply	200 ply

Notes:

1. Parasol stiffening elements (battens) have the following dimensions:

   Thickness = 0.1 In.

   Width = 1-1/2 In.

   Length ≈ 12 In

   The battens are made from glass reinforced plastic (Scotchply 1002) The fibers are unidirectional and are parallel to the long side of the batten. The batten material properties are as follows:

Room Temp. and Dry	Flexural Strength	= 165,000 psi
	Modulus in Flexure	= 5.3×10^6 psi
	Tensile Strength	= 160,000 psi
	Specific Gravity	= 1.8

2. Alternate seal coating may be Chemigum vinyl (Goodyear M-521) fabric type, maybe Goodyear H391.

6.3 ELECTRICAL SYSTEM

Electrical systems were developed only to the level of detail required for weight and cost estimation.

6.3.1 SYSTEM DESCRIPTION -- The electrical power system selected for applicability to each ship concept consists of three approximately sized 60 Hz diesel generators connected in a ring bus distribution systems with two generators operating and one on standby for primary power. The power provided by the two operating diesel engines is adequate to satisfy the ship's electrical power requirements under all operating conditions. A diagram of the electrical power distribution concept is shown in Firure 6.3-1.

6.3.2 GENERATOR SELECTION -- Diesel engine driven generators were selected on the basis of an evaluation of prime mover performance versus total weight (that is, equipment installed weight plus fuel consumed as a function of time.) Gas turbine prime movers offer lower weight for a given power output level; however, at the present state of development the fuel consumption rate which results in lower total weights (prime mover plus fuel) for some missions. A comparison of the total weight of gas turbine and diesel engine driven electrical power generator systems relative to ship's mission duration is shown in Figure 6.3-2.

6.3.3 ELECTRICAL LOAD ANALYSIS AND SYSTEM SELECTION -- A preliminary electrical load analysis was performed for each concept to provide a basis for system selection. In each case a reasonable power margin was provided for potential increased requirements resulting from more detailed analysis and for possible growth in the electrical power demand through the ship's life. The results or this analysis are summarized in Table 6.3-1.

6.4 COMMAND, COMMUNICATION AND CONTROL SYSTEM

The command communication and control system consists of three major subsystem groups:

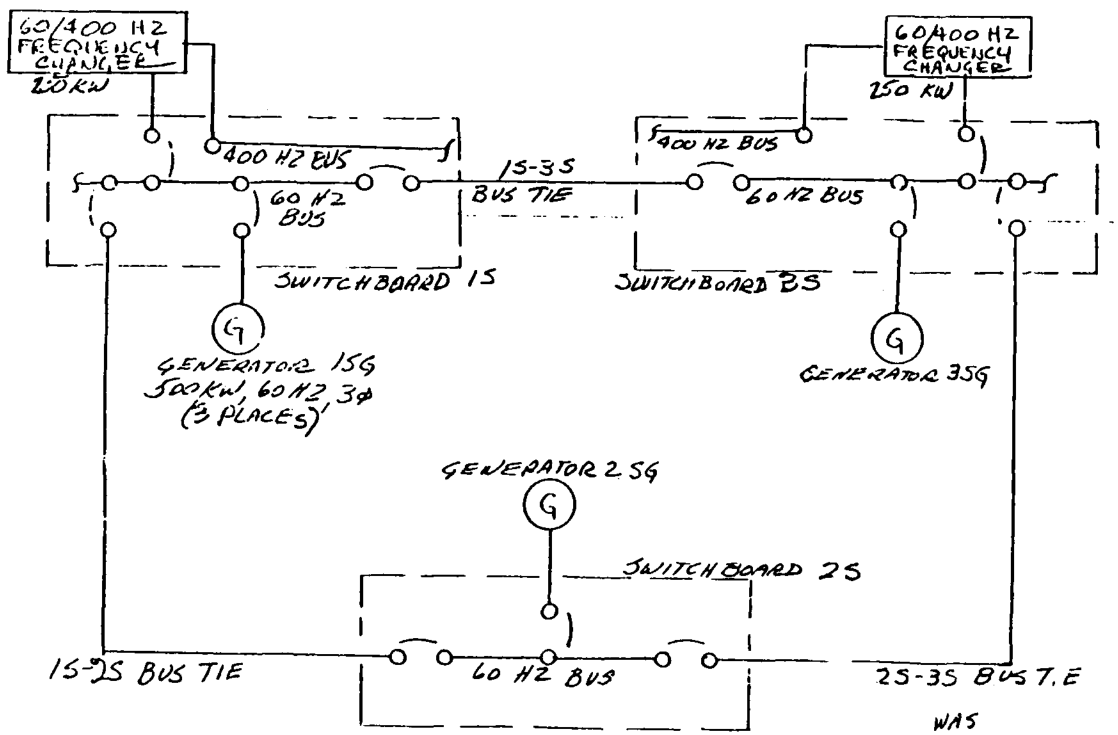


Figure 6.3-1. Power System Distribution Diagram

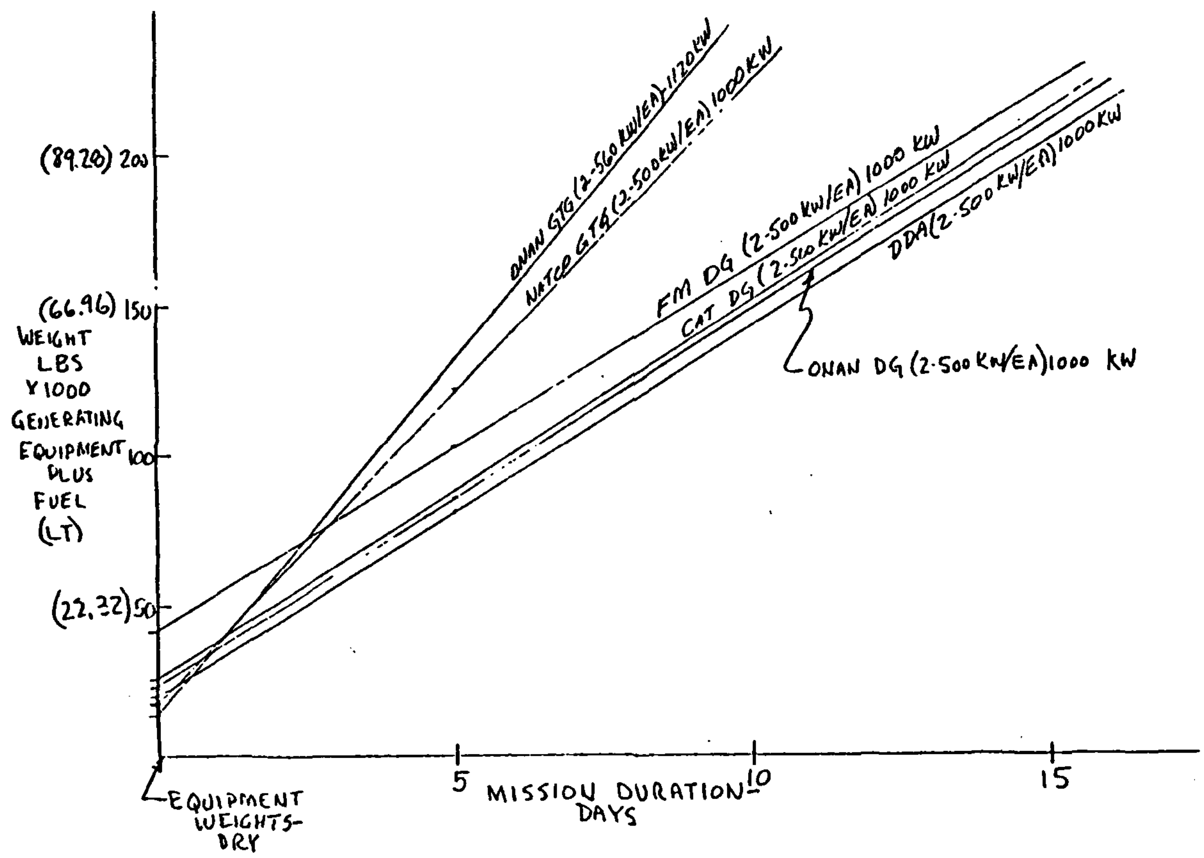


Figure 6.3-2. Comparison - Electric Generating Equipment and Fuel Weight Versus Mission Duration

Table 6.3-1. Estimated Electrical Power Requirements

SHIP CONCEPT	TOTAL EST. CONN. LOAD (KW)	LOAD FACTOR (AV)	PRODUCT (KW)	MARGIN (%)	POWER REQUIRED (KW)
WHEC-SES	926	0.70	649	25	865
WMWC-SES	841	0.70	589	25	785
WLB-SES	263	0.70	184	28	245
WPC-SES	91	0.70	64	25	85

1. Military systems including combat intelligence center equipment, gun or missile fire control systems and surveillance systems.
2. Communication including exterior and interior communication, navigation and related elements.
3. Ship and machinery control elements.

The items for Group 1 were derived directly from specified design requirements discussed in Section 3. The scope of investigation for Groups 2 and 3 was constrained to the level of detail required for space and weight estimation as appropriate to the concept design stage of development.

6.4.1 MILITARY, NAVIGATION AND COMMUNICATION SYSTEMS -- The equipments identified in these systems are listed in Table 6.4-1. Navigation and communication systems equipment were selected as deemed appropriate to the size and mission of each ship concept. Equipments were identified only in the generic sense in that identification to the component and manufacturer level was considered inappropriate for this study.

6.4.2 SHIP AND MACHINERY CONTROL -- The scope of this study was restricted to the identification and preliminary definition of that portion of the ship control system concerned with the control and monitoring of propulsion, steering and lift machinery. The control concept presented is basically applicable for the propulsion power plants and lift systems for all ship concepts. Differing numbers, sizes and configurations of engines for each system require addition or deletion of basic controls, displays supporting equipment. Alternative control systems may be selected with mininal impact upon the designs.

The major features of the Ship Control System are:

- Use of a computer to implement a "Management by Exception" control-display philosophy for monitoring machinery performance and for selecting operational conditions at the Engineering Consoles for the Central Control Station.

Table 6.4-1. Communication and Navigation Equipment

WHEC-SES	WMEC-SES	WLB-SES	WPC-SES
CIC: NONE	CIC: AUTOMATED CIC (COMDAG)	CIC: NONE	CIC: NONE
FIRE CONTROL MK92 GFCS	FIRE CONTROL MK92 GMS	FIRE CONTROL None	FIRE CONTROL NONE
SURVEILLANCE AN/SLQ-32 TOWED ARRAY SONAR	SURVEILLANCE AN/SLQ-32 TOWED* ARRAY SONAR	SURVEILLANCE None	SURVEILLANCE NONE
NAVIGATION RADAR (COLLISION AVOIDANCE)- 2 SYSTEMS LORAN-C SATNAV RDF GYRO FATHOMETER SPEED LOG WIND SPEED AND DIRECTION	NAVIGATION RADAR (COLLISION AVOIDANCE) - 2 SYSTEMS LORAN-C SATNAV RDF GYRO FATHOMETER SPEED LOG WIND SPEED AND DIRECTION	NAVIGATION RADAR (COLLISION AVOIDANCE) - 2 SYSTEMS LORAN-C SATNAV RDF GYRO FATHOMETER SPEED LOG WIND SPEED AND DIRECTION	NAVIGATION RADAR (COLLISION AVOIDANCE) - 2 SYSTEMS LORAN-C SATNAV RDF GYRO FATHOMETER SPEED LOG WIND SPEED AND DIRECTION
COMMUNICATIONS VHF (2 SYSTEMS) SSB-HF (2 SYSTEMS) INTERIOR COMM. INTERIOR TELEPHONE	COMMUNICATIONS VHF (2 SYSTEMS) SSB-HF (2 SYSTEMS) INTERIOR COMM. INTERIOR TELEPHONE	COMMUNICATIONS VHF (2 SYSTEMS) SSB-HF (2 SYSTEMS) INTERIOR COMM. INTERIOR TELEPHONE	COMMUNICATIONS VHF (2 SYSTEMS) SSB-HF (2 SYSTEMS) INTERIOR COMM. INTERIOR TELEPHONE

- Critical signals are hardwired and provided with dedicated controls and displays.

- The ship operator and assistant ship operator are provided with conventional marine controls and displays in the pilot house for maneuvering control.

- Dual Remote Control Stations plus Local Controls and positive safety interlocks.

Control and display requirements: The selected system was derived on the basis of a prior study in which four candidates control system configurations were evaluated:

Candidate 1 -- A single ship control station remote from propulsion/lift machinery spaces.

Candidate 2 -- Two remote control stations, one primarily designed for maneuvering control with the other designed for propulsion and lift control; redundancy provided by allocating control and monitoring capability of vital functions to both stations.

Candidate 3 -- A single remote ship control station with redundant local control and monitoring of vital functions in engineering spaces.

Candidate 4 -- Two remote control stations, one primarily for maneuvering control with the other for propulsion and lift control, with redundant control and monitoring of vital functions, additional redundant control of vital functions provided at local control station in engineering spaces.

A comparison of the four alternatives with respect to various considerations is presented in Table 6.4-2. It was assumed that vital ship control function signals require design features which preclude their loss due to single failures. Therefore, since vital functions have at least two levels

Table 6.4-2. Control Station Alternatives

	Alternative 1 Single Remote Control Station	Alternative 2 Dual Remote Control Stations	Alternative 3 Single Remote Control Station Plus Local Control	Alternative 4 Dual Remote Control Stations Plus Local Control	Remarks
Redundancy and Vital Functions (1)	4	2	3	1	Local control stations provide additional redundancy to remote control/monitoring capability.
Survivability	4	3	2	1	Alt. 3 provides more diversification and physical separation than Alternative 2.
Manning	1	2	3	4	With 2 watchstanders at remote stations and one at local stations, Alt 3 is more sensitive to loss of single watchstander than Alt 2.
Marine Experience	4	3	2	1	Provides for standard marine repair and backup operations.
Weight	1	2	3	4	Assumes local control stations have hard wired, single purpose controls/displays while remote stations utilize multi-purpose controls/display.
Cost	3	4	1	2	Assumes integration of local control functions into remote stations is more expensive than providing separate local control stations.
Summation	17	16	14	13	
Overall Pref. (3)	4	3	2	1	

1. Redundancy and vital functions categories were combined because all vital functions will have at least two levels of redundancy.

2. Orders of preference in the table are: 1 = most preferred, 2 = second preference, 3 = third preference, 4 = least preferred

3. Most preferable alternative is that with lowest summation number.

of redundancy in each alternative, the categories of "redundancy" and "vital functions" were combined. Information transfer rate and process time were not considered because differences due to equipment location/configuration should be negligible in a hardwired system. Equipment availability is expected to be high since conventional marine technology is being used.

On the basis of the evaluation summarized in Table 6.4-2, the preferred arrangement is Alternative No. 4 which reflects conventional naval ship practice and emphasizes survivability and functional orientation. Local control panels are provided for maintenance and backup under adverse operating conditions.

The two remote control stations are the Pilot House and the Central Control Station. The Pilot House serves as the primary control station for ship maneuvering and piloting, navigation, tactical command, collision avoidance, and interior communications. Limited control of propulsion/lift machinery is afforded in the Pilot House to the extent that it contributes to positive ship directional control. The Central Control Station serves as the primary control station for all ship engineering and auxiliary support functions. Control/monitor capability for propulsion, lift, auxiliaries, electrical and damage control functions are provided at the Central Control Station.

A certain amount of commonality is necessary between the control system functions assigned to the Pilot House and Central Control Station. Vital ship functions, such as propulsion/lift, engine throttle control and communications capability are duplicated between the two spaces for reliability and safety. Additionally, certain alarms are presented in summary fashion at the Pilot House, with functional control of the monitored equipment being assigned to the Central Control Station. A summary allocation of the major ship control functions is presented in Table 6.4-3.
Redundancy is provided for vital functions with: 1) control consoles in the Pilot House and Central Control Station, 2) spatially separated dual remote control paths, and 3) local control.

Table 6.4-3. Command/Monitor Function Locations Summary

REQUIRED COMMAND/ MONITOR CAPABILITY	C/M LOCATION			NOTES
	PILOT HOUSE	CENT. CONT. STA.	LOCAL	
1. Propulsion Plant				1: Pilot House Control provides for maneuvering & attitude control.
a. Propulsion engines	X[1]	X	X[2]	
b. Propeller & shaft	X[1]	X		
2. Lift System				2: Local control stations provide complete engine control for emergency operations, maintenance and repair activity external to engine enclosures.
a. Lift engines	X[1]	X	X[2]	
b. Fans & air distribution	X[1]	X		
c. Seals	X	X		
3. Climate Control				
a. HVAC		X	X	
b. Refrigeration		X	X	
4. Sea Water		X	X	
5. Drainage		X	X	
6. Fresh Water		X	X	
7. Fuel & Lube Oil		X	X	
8. Air, Gas, and Miscellaneous Fluid				
a. Compressed air		X	X	3: A secondary helm position is available in the Central Control Station. In addition, after steering stations provide emergency steering capability
b. Hydraulic		X	X	
c. Fire Detection & extinguishing	X	X	X	
9. Electrical Plant		X	X	
10. Maneuvering Controls				
a. Steering	X	X[3]	X[3]	
b. Thrust direction	X	X		
c. Ride control	X			

6.4.2.1 System Description — The principal features of the ship control system are:

a. Conventional hardwired signal distribution system.

b. Two principal control stations, Pilot House and Central Control Station.

The Pilot House will serve as the primary vessel operational control station and will provide control/monitor capability for the following functions:

1. Propulsion Plant (Control limited to positive maneuvering and attitude control).
2. Lift System (Control limited to positive maneuvering and attitude control.
3. Fire detection and extinguishing.
4. Operational Controls (Steering, thrust direction, and ride control).

The Central Control Station will serve as the primary vessel engineering control station, and provide control/monitor capability for the following functions:

1. Propulsion Plant
2. Lift System
3. Climate Control
4. Seawater System
5. Drainage System
6. Fresh Water System
7. Fuel and Lube Oil System
8. Air, Gas and Miscellaneous Fluids
9. Electrical Plant
10. Damage Control

Variations to the basic Ship Control System that are made necessary by alternative propulsion/lift machinery arrangements or mission requirements will be related primarily to cable and sensor quantity and control/display

station panel additions and items such as the number of control/input and special signal processing needs.

A dual electro-hydraulic control system is provided for each rudder. A rudder position feedback signal is provided. Rudder movement is accomplished by one of two hydraulic actuators controlled by a closed loop servo system. Each rudder control system is independent of, but synchronous with the other. Both are located near the rudders. Emergency rudder operation is provided at the hydraulic pumps or with mechanical leverage. Remote steering controls are provided at the ship control console in the Pilot House and the Engineering Control Console in the Central Control Station.

The maneuvering and steering control function block diagram, is shown in Figure 6.4-1. All the ship operator control station inputs are wired direct to an effector control unit.

The functional diagram indicates that thrust is controlled by operator actuation of two levels, one for port and one for starboard propulsion plants. At both the Ship Control Console and Engineering Control Console, the levers can either be ganged or operated independently for steering with differential thrust.

For the CODOG plant (WHEC),this craft is operating at low speed and cruise using diesel propulsion. The diesel lift power levers are rendered inoperative and the propulsion control levers are coupled to the diesel control system , switching being performed within the Combined Diesel or Gas Turbine (CODOG) control system. A status indication is provided to the operator to show the CODOG operational condition. Local propulsion, lift and rudder control is available if failures occur at both the Ship Control and the Engineering Control Consoles.

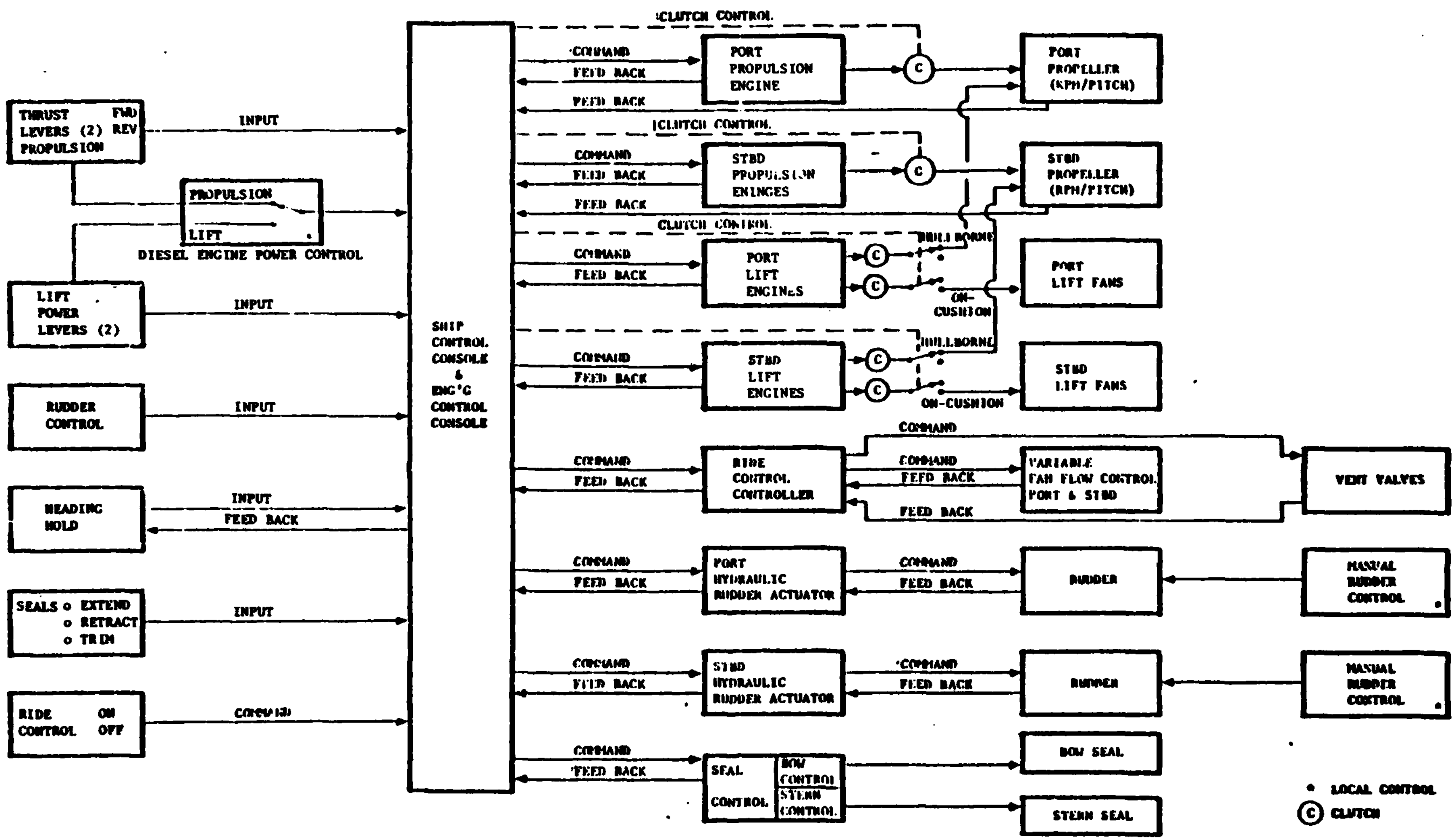


Figure 6.4-1. Maneuvering and Control System Functional Block Diagram

Control of the retraction system for bow and stern seals is included in Figure 6.4-1 to complete the representation of the lift system. The single block represents two controls, one for the bow seal and one for the stern seal. This is necessary because, depending on operating conditions, it may be advantageous to independently set bow and stern seal extension/ retraction. The controls can be ganged, so that the bow and stern seals can be raised and lowered synchronously or asynchronously.

Figure 6.4-2 illustrates the machinery control concept. The diagram is typical for the independent port and starboard CODOG power of the WHEC concept.

In the diesel powered mode, the thrust levers in the Pilot House or tnat the Central Control Station are used to control the power level of the diesel engines which drive the propellers through the gear boxes and air clutches. The gas turbines are shut down and the turbine automatic clutches are disengaged. The lift fans may be de-clutched from the diesel engines for off-cushion operation.

The gas turbines may also provide propulsion while the ship is hullborne. In this mode the automatic clutches engage when gas turbine input shaft speeds are properly synchronized, thereby connecting turbine drive to the propeller gearboxes. All diesel engine clutches are disengaged and thrust levers are used to control the power levels of the gas turbines.

Figure 6.4-3 illustrates the concept ship control console panel arrangement. The principal features of the panel arrangement are as follows:

a. Two navigation system CRT displays
b. A shared center panel and horizontal console extension to present critical controls to either ship operator station.
c. Summary alarms located on the upper periphery of the console.
d. Critical course keeping data located above the CAS display at the SCS station (magnetic and gyrocompass headings and ship speed).

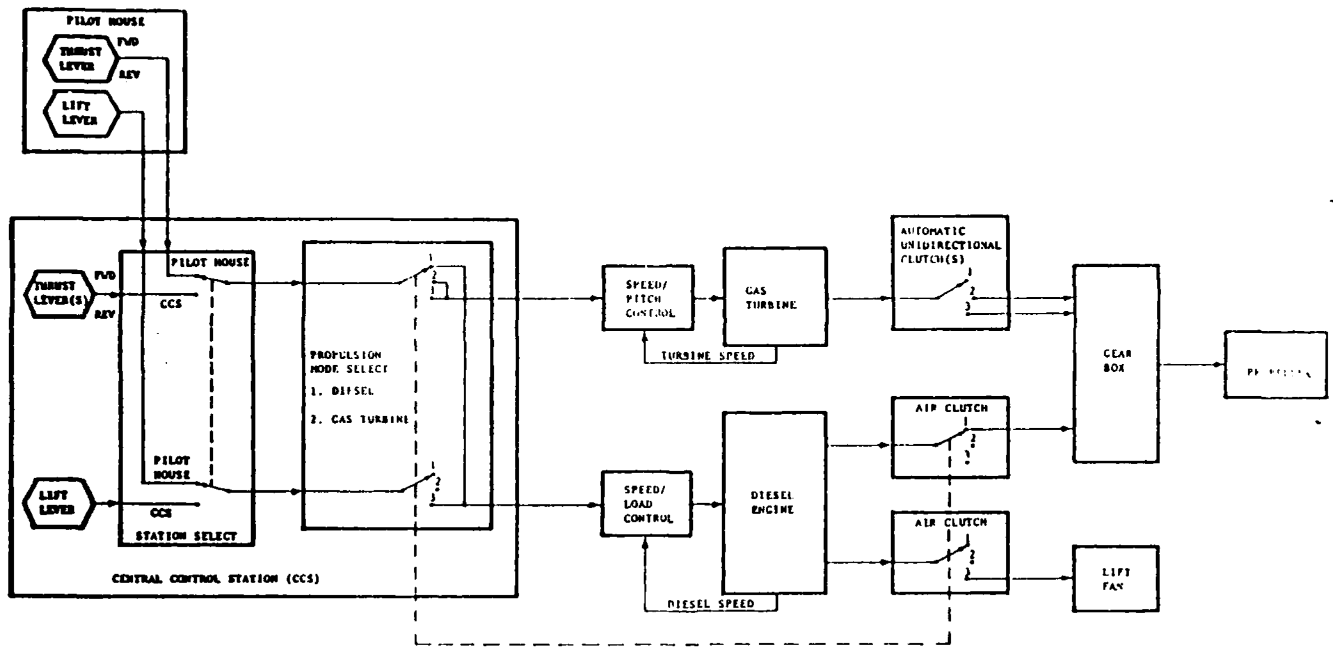


Figure 6.4-2. Propulsion and Lift Machinery Control System Functional Block Diagram - Typical: Port and Starboard (WHEC Concept)

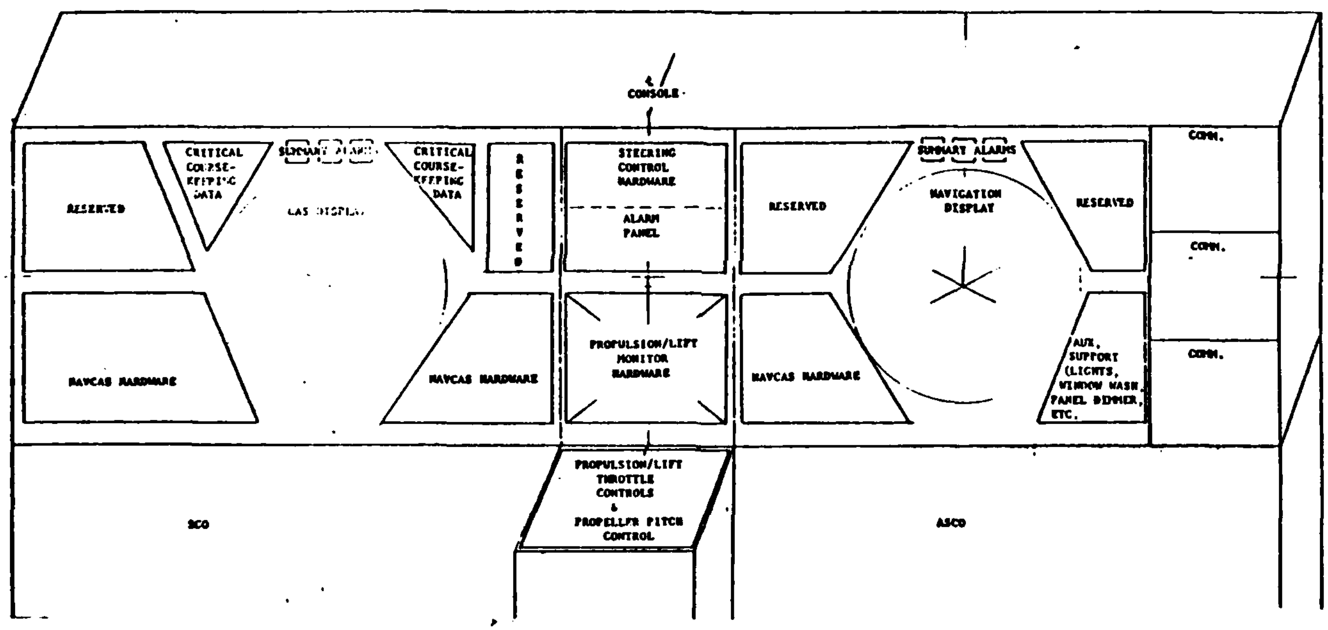


Figure 6.4-3. Ship Control Console

Figure 6.4-4 illustrates the conceptual panel arrangement on the Propulsion/Lift Control and Auxiliary and Electical Control Consoles. The panel arrangement of the Damage Control Console would be similar to that of the Propulsion/Lift Control and the Auxiliary and Electrical Control Console and the Auxiliary and Electrical Control Console are:

a. Functionally oriented panel arrangements. Where applicable, the controls and displays are presented in a layout representative of the shipboard locations of the equipment or support systems on the left and forward systems at the top.

b. Summary alarms located in the upper periphery of the consoles. This feature helps ensure that the console operator will notice displayed alarm data regardless of ambient noise conditions. Dedicated alarms in the Central Control Station Consoles will be physically located adjacent to the controls for the system or function monitored, aiding the operator in rapid problem identification.

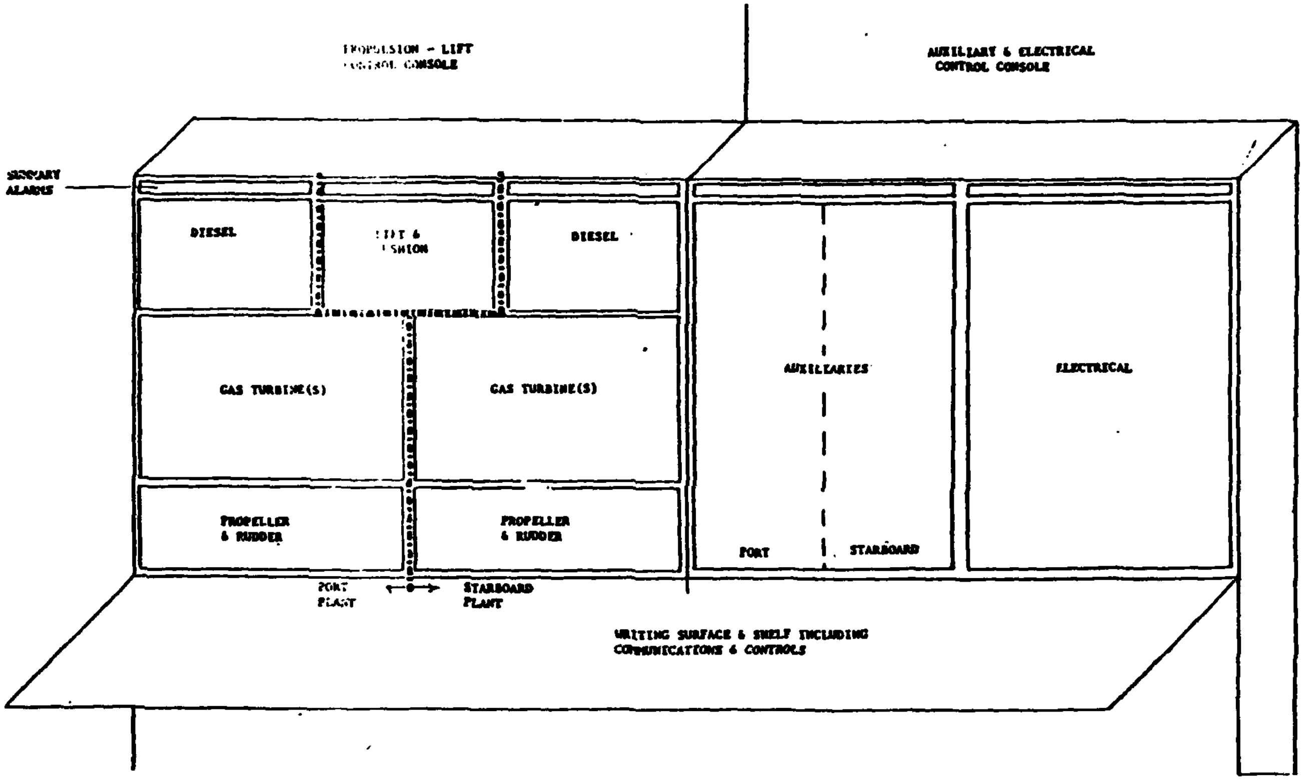


Figure 6.4-4. Conceptual Panel Arrangement

6.5 CRITICAL AUXILIARY SUBSYSTEMS

A review of all the SWBS 500 elements was conducted and a matrix establishing a level of criticality was constructed. Definitions and ratings were assigned to specific levels of criticality relative to considerations of technical feasibility and influence upon the ship design. Each SWBS 500 element rating provided a hierarchy from which particular systems were identified as requiring special study.

The definitions used for this analysis were as follows:

Technology Critical (rating of 5)	-	A system or element which is required for mission critical but has not been previously engineered for SES applications.
Mission Critical (rating of 4)	-	A basic system or element which is re quired to allow the craft to be operational.
Capability Critical (rating of 3)	-	A system or element which is required to demonstrate capability relative to essential support operations e.g., helicopter operations, etc.
(4) Design Critical (rating of 2)	-	A system or element which has previous SES engineering but required modifications to suit optimum craft configuration.
(5) Non-critical	-	Existing technology satisfactory.

Ratings were assigned to these five definitions and all auxiliary systems evaluated as shown in Table 6.5-1. On the basis of this evaluation the following systems were selected for specific review within the scope of this study.

- Sea Water System
- Ships Fuel System
- Steering System
- Aircraft Recovery System

All other elements are considered non-critical and descriptions for these systems were limited to the estimation of spaces required, if necessary to support ship concept definition and weight estimation.

6.5.1 SEA WATER SYSTEM -- The seawater systems include all the seawater services required for any oceangoing craft supporting hotel, cooling, damage control and magazine sprinkling functions. The preliminary seawater system consists of firemain pumps distributing seawater through a horizontal firemain loop located above the damage control deck, providing seawater service to individual users through pressure reducing stations and appropriate insolation valves. The distribution of seawater from the firemain pumps follows conventional practices.

The firemain pumps are sized to provide maximum seawater demand with one unit down, and are driven by 60 Hz electric motors.

The firemain pumps are arranged into two symmetrical pump configuration, port and starboard. Each group of firemain pumps are located as low as possible within the sidehulls in the space designated as auxiliary machinery room(s). The supply of seawater to each firemain pump is from dedicated seachests located in the lower outboard section of the sidehull. The arrangement is shown in Figure 6.5-1.

Table 6.5-1. Auxiliary Systems Criticality Matrix

SWBS	AUXILIARY SYSTEMS CRITICALITY MATRIX — RATING →	TECHNICAL 5	MISSION 4	CAPABILITY 3	DESIGN 2	NON-CRITICAL 1	CRITICALITY
506	Overflows, Air Escapes and Sounding Tubes					X	1
510	CLIMATE CONTROL						
511	Compartment Heating System					X	1
512	Ventilation System		X		X		6
513	Machinery Space Ventilation System		X	X	X		9
514	Air Conditioning System		X	X	X		9
516	Refrigeration System					X	1
520	SEA WATER SYSTEMS						
521	Firemain and Flushing (Sea Water) System	X	X	X	X		14
522	Sprinkler System		X		X		6
524	Auxiliary Sea Water System		X		X		6
526	Scuppers and Deck Drains					X	1
528	Plumbing Drainage					X	1
529	Drainage and Ballasting System			X	X		5
530	FRESH WATER SYSTEMS						
531	Distilling Plant					X	1
532	Cooling Water				X		2
533	Potable Water					X	1
534	Aux. Steam and Drains Within Machinery Box (Machinery Drains)					X	1
536	Auxiliary Fresh Water Cooling				X		2
540	FUELS AND LUBRICANTS, HANDLING AND STORAGE						
541	Ship Fuel and Fuel Compensating System	X	X	X	X		14
542	Aviation and General Purpose Fuels		X	X	X		9
545	Tank Heating (Diesel Heating)					X	1
549	Special Fuel and Lubricants, Handling & Stowage				X		2

SWBS	AUXILIARY SYSTEMS CRITICALITY MATRIX — RATING →	TECHNICAL 5	MISSION 4	CAPABILITY 3	DESIGN 2	NON-CRITICAL 1	CRITICALITY
550	AIR, GAS, AND MISC. FLUID SYSTEMS						
551	Compressed Air Systems		X		X		6
552	Compressed Gases					X	1
553	O_2 N_2 System					X	1
555	Fire Extinguishing Systems		X	X	X		9
556	Hydraulic Fluid System				X		2
560	SHIP CONTROL SYSTEMS						
561	Steering and Diving Control Systems	X	X	X	X		14
562	Rudder	X	X	X	X		9
565	Trim and Heel (Roll Stabilization)			X	X		5
570	UNDERWAY REPLENISHMENT SYSTEMS						
571	Replenishment-At-Sea			X	X		5
572	Ship Stores and Personnel and Equipment Handling					X	1
573	Cargo Handling			X	X	X	6
574	Vertical Replenishment Systems			X	X		[illegible]
580	MECHANICAL HANDLING SYSTEM						
581	Anchor Handling and Stowage Systems		X	X	X		9
582	Mooring and Towing Systems		X	X	X		9
583	Boat Handling and Stowage Systems			X	X		5
584	Mech. Operated Door, Gate, Ramp, Turntable Sys.			X	X		5
586	Aircraft Recovery Support Systems	X	X	X	X		14
588	Aircraft Handling, Servicing and Stowage			X	X		5
590	SPECIAL PURPOSE SYSTEMS						
593	Environmental Pollution Control Systems		X	X	X		9
598	Auxiliary Systems Operating Fluids					X	1

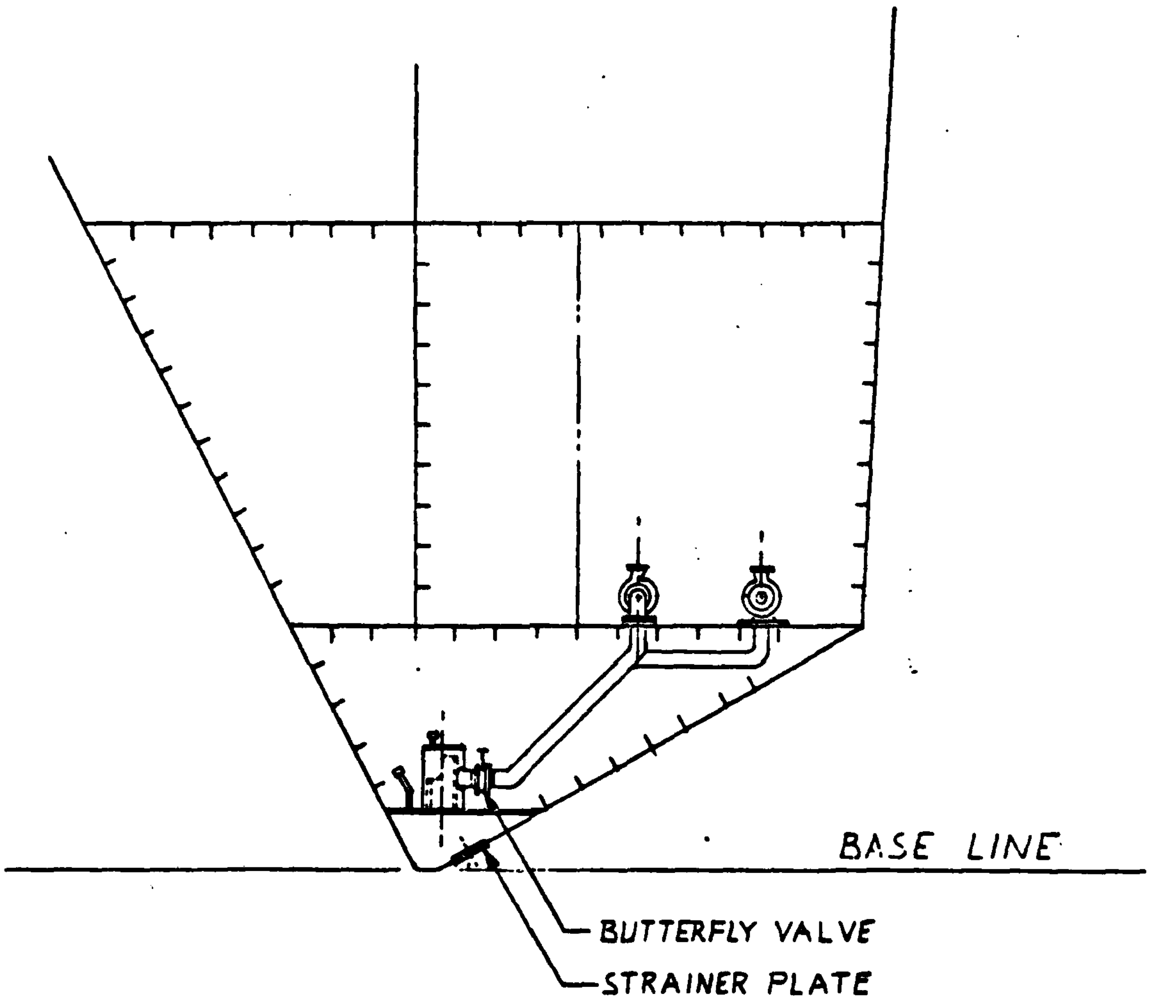


Figure 6.5-1. Sea Water Pump

The seachest has been designed to operate under all craft conditions. It incorporates a "high hat" section which collects entrapped air permitting proper venting. The seachest employs a special inlet strainer plate such as shown in Figure 6.5-2 which functions as both a low speed (off-cushion) and a high speed (on-cushion) inlet. The low speed section is designed to limit the velocity of incoming seawater to a maximum of 5 feet/second. The high speed section employs a drop lip inlet which regulates the flow of free stream seawater into the seachest. The total pressure within the seachest cavity is maintained at approximately 15 psi during high speed operations by increasing inlet losses due to restrictions in the high speed section of the inlet strainer plate. The exact position of the seawater inlet is dependent upon flow characteristics acoss the sidehulls and the propensity of the craft to roll and pitch. Investigation into broaching and the generated wave profile will be required to support the final seawater inlet design.

6.5.2 SHIP FUEL SYSTEM -- The ship fuel system provides storage, trim and transfer, purification, and distribution of the ship's distillate fuel from receipt of fuel to the fuel consuming end-user.

The fuel system's purification, filtering, and pumping equipment is capable of processing either JP-5 and/or DFM distillate fuels. The block diagram presented in Figure 6.5-3 shows the ship fuel system interfaces.

6.5.3 STEERING SYSTEM -- The steering system investigated consisted of the steering mechanism, and the controls associated with their operation, suitable for installation in propeller driven surface effect ships. Differential thrust using variable controlled pitch propellers was recognized as augmenting the maneuvering capabilities, but was not considered the basic maneuvering mechanism. The rudder design would be developed using standard naval and marine practices and the USCG requirements for steering systems as the governing criteria.

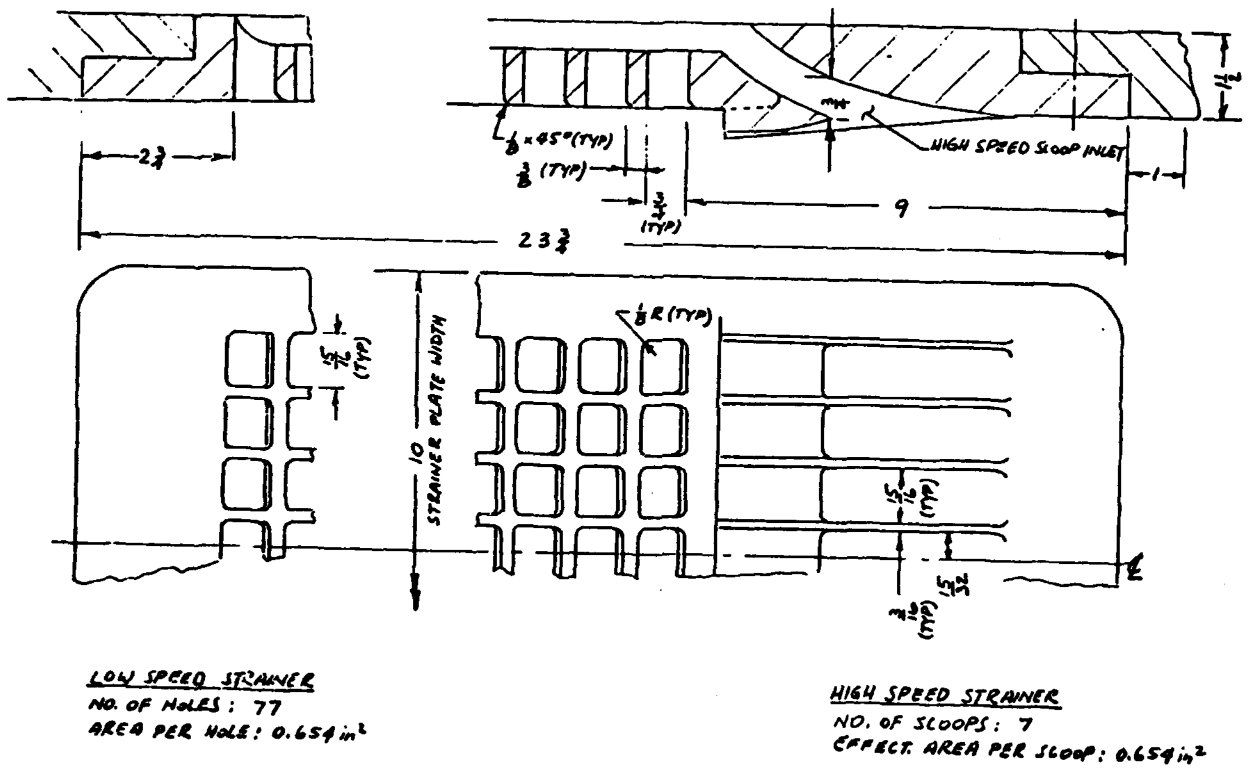


Figure 6.5-2. Strainer Plate

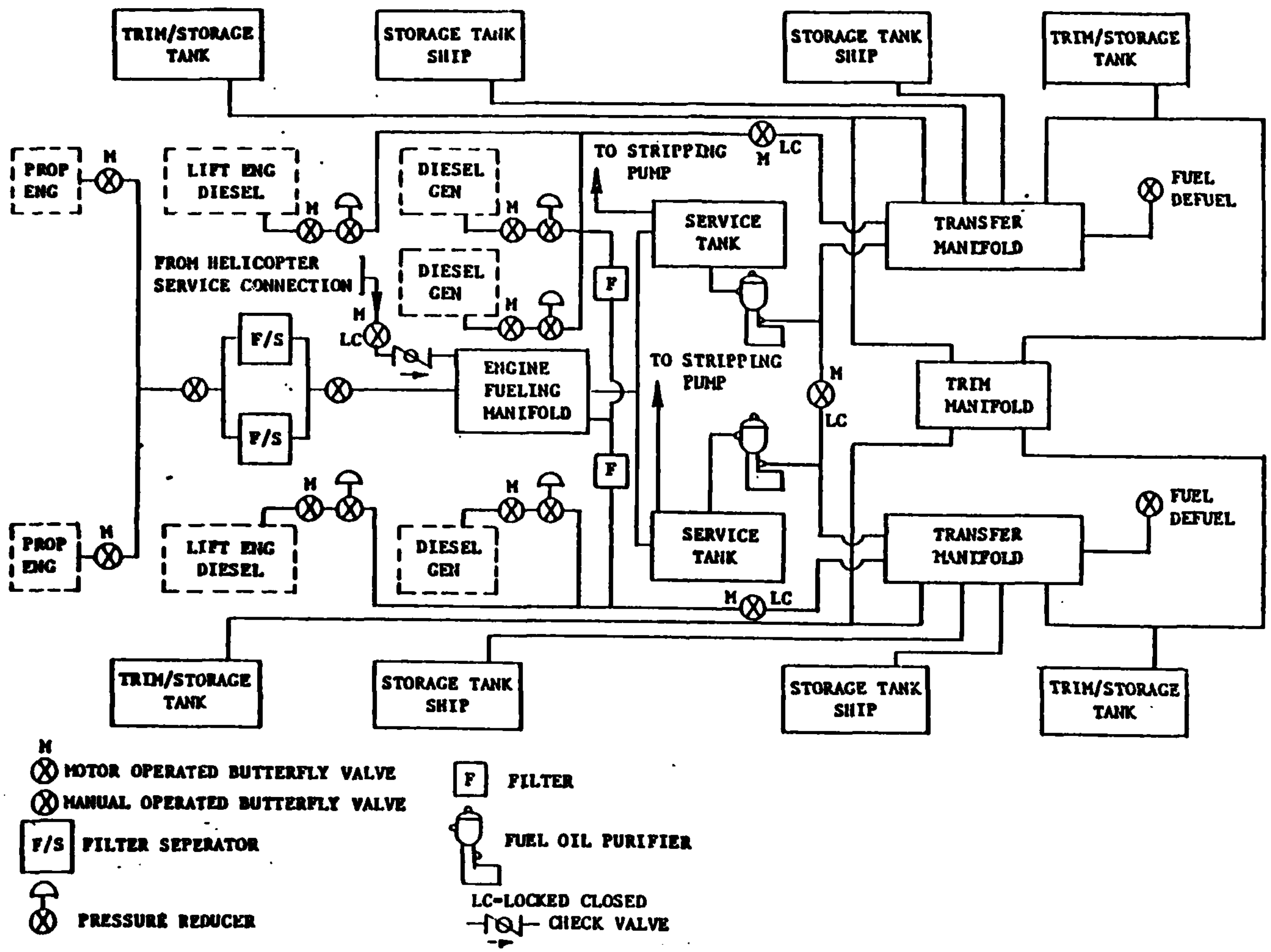


Figure 6.5-3. Ship Fuel Oil System - Block Diagram

The steering systems investigated were selected from the family of electrohydraulic units presently available. These units consist of linkage type, Rapson slide, and rotary vane gear. All units are powered by self contained hydraulic power units.

The rotary vane gear consists of a high torque low speed hydraulic actuator mounted directly upon the rudder stock and powered by dual hydraulic pumps. Although for conventional ship applications this installation offers reduced weight and space compared to Rapson slide, they are larger and heavier than other systems for low torque SES platforms. In addition, from a maintenance and servicing standpoint they are less desirable than the other conditions in that removal of the entire unit is required to permit repair or servicing.

The rotary vane gear does not permit redundancy in rudder operation should the actuator (gear) fail. To comply with USCG requirements a complete auxiliary steering system would be required in addition to the main system. This arrangement would be cumbersome and heavy.

The Rapson slide type is normally used for extremely high torques in excess of 15,000 inch-pounds. Due to their high weight and large installation space requirement, this unit is not suitable for SES platforms.

The linkage type system consists of double-acting hydraulic cylinders, clevis mounted. The cylinders attach directly to the tiller arm providing positive actuation. The hydraulic cylinders share the load and may be designed to provide complete redundancy. Figure 6.5-4 shows an arrangement of a linkage type steering gear system. This arrangement provides maximum serviceability and requires the least installation space as compared with the rotary vane and Rapson slide type steering gears.

The linkage type steering gear is commercially available, USCG approved, and has a history of marine applications.

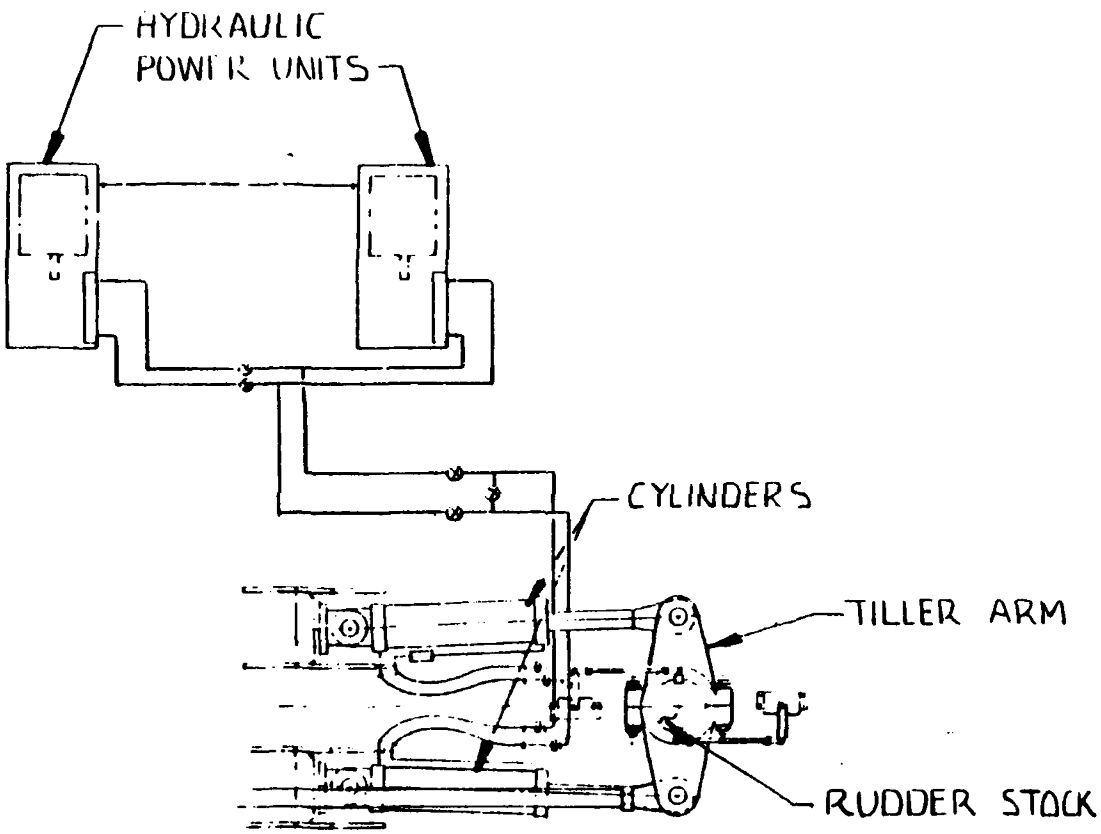


Figure 6.5-4. Linkage Type Steering Gear

6.5.4 HELICOPTER RECOVERY SYSTEM -- The Recovery, Assist, Securing, and Traversing (RAST) system was reviewed by the Naval Air Engineering Center for application to surface effect ships for the purpose of space allocation. A RAST winch room arrangement concept was developed and is shown in Figure 6.5-5. However, testing conducted with the SES 200 indicates that a haul down system will not be necessary for deployment of helicopters from an SES.

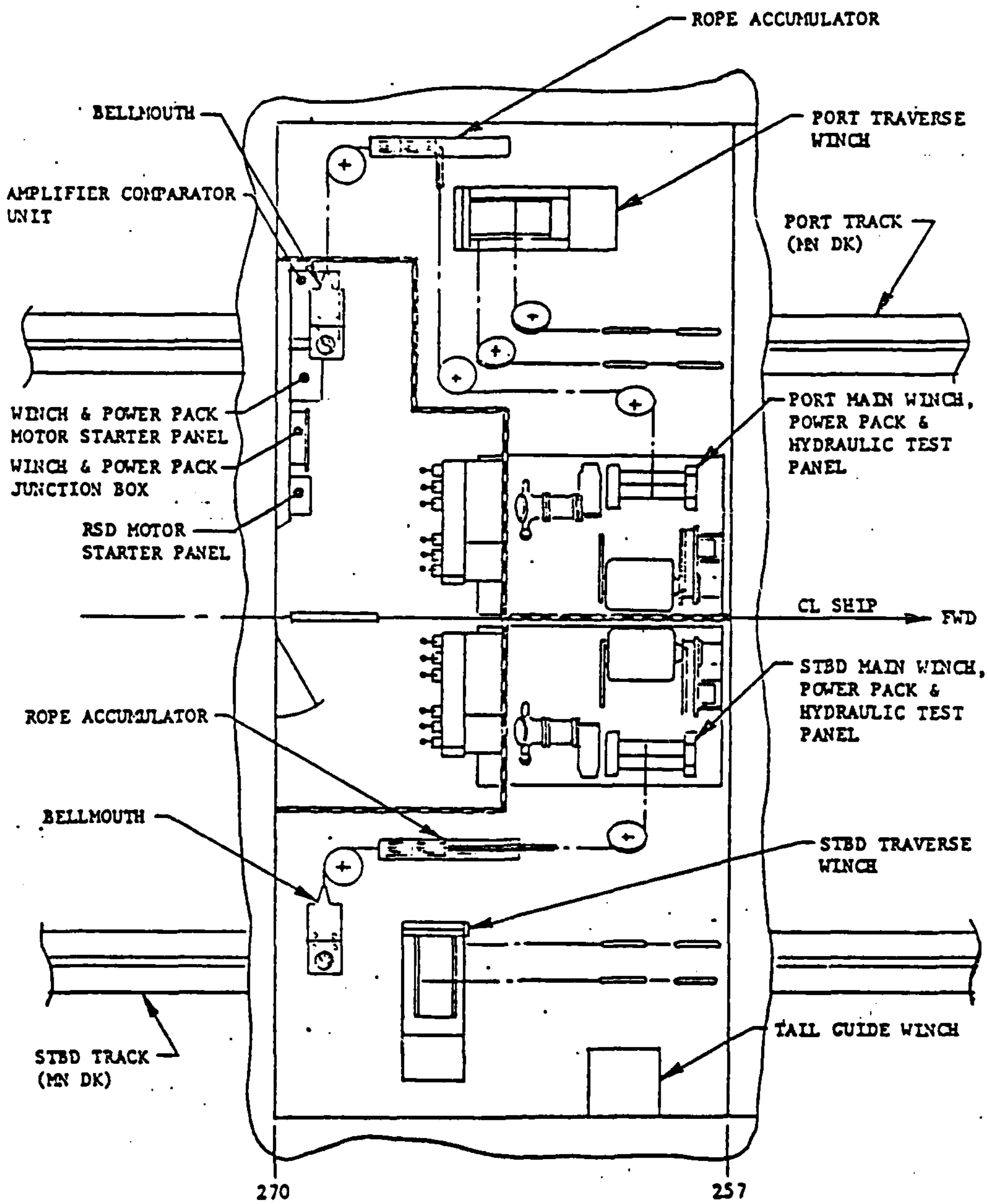


Figure 6.5-5. RAST Winch Room Arrangement

7 / REFERENCES

1-1 U. S. Coast Guard Research and Development Center Report No. CG-D-44-32 dated August 1982, "Technical and Operational Evaluation of USCGC Dorado (WSES-1)", (LCDR M. J. Goodwin).

1-2 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "Medium Displacement Combatant Surface Effect Ship".

1-3 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Producibility Improvement Study - Ships Characteristics and Performance Report", dated 18 November 1981. (Contract No. N00024-77-C-2032, CDRL No. E06C).

2-1 Naval Sea Systems Command Surface Effect Ship Project Office (PMS-304) Technical Report, "3KSES Producibility Improvement Study - Model Test and Data Analysis Report (Performance)", dated 18 December 1981. (Contract No. N00024-77-C-2032, CDRL No. E06C)

2-2 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Producibility Improvement Study - Drag, Speed, and Range Report", dated 23 November 1981. (Contract No. N00024-77-C-2032, CDRL No. E06C)

2-3 Naval Sea Systems Command Surface Effect Ship Project Office (PMS-304) Technical Report, "3KSES Producibility Improvement Study - Stability Report".

2-4 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Program Stability and Maneuverability Report". (Contract No. N00024-77-C-2032, CDRL E03L)

2-5 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Producibility Improvement Study - Model Test and Data Analysis Report (Structural Loads)", dated 23 December 1981. (Contract No. N00024-77-C-2032, CDRL No. E06C.)

2-6 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Producibility Improvement Study - Structural Loads Report," dated 23 December 1981. (Contract No. N00024-77-C-2032, CDRL No. E06C.)

2-7 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Program - Hydrodynamics/Loads Test Data Analysis and Correlation Report," dated 23 December 1977. (Contract No. N00024-77-C-2032, CDRL No. E031.)

2-8 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Program - Structural Response Analysis Report with Calculations," dated 6 November 1978. (Contract No. N00024-77-C-2032, CDRL No. E02W).

2-9 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Program - Panel and Element Test Data Analysis and Correlation Report". (Contract No. N00024-77-C-2032, CDRL No. E02Z.)

2-10 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Producibility Improvement Study - Hull Structure Summary Report", dated 28 August 1981. (Contract No. N00024-77-C-2032, CDRL No. E06C.)

2-11 Naval Sea Systems Command Surface Effect Ships Project Office (PMS-304) Technical Report, "3KSES Producibility Improvement Study - Critical Auxiliary Systems Summary REport - Appendix F - Ride Control System Report Task F, Subtask 6," dated 15 September 1981. (Contract No. N00024-77-C-2032, CDRL No. E06C.)

5-1 SES Producibility Study, Drag, Speed and Range Report (PMS-304), dated 16 November 1981.

5-2 SES Producibility Study, Model Test, Final Report (PMS-304), dated 16 November 1981.

5-3 Navy Report No. DTNSRDC-82/109, dated January 1983, "Methods of Predicting the Drag, Speed, and Range of Surface Effect Ships", (Steven M. Wells).

5-4 SES Producibility Study, Stability Report (PMS-304), dated 16 November 1981.

5-5 Navy Report DTNSRDC/ASD-78/11, dated April 1978. "Captive Model Experiments with High Length-to-Beam Surface Effect Ships," (S. J. Chorney and R. W. Walker).

5-6 DDS079-1, Stability and Buoyance of U. S. Naval Surface Ships.

5-7 Effects of Simulated Surface Effect Ship Motions on Crew Habitability - Phase II, Volume 1, Summary Report. Report No. TR1070 (PMS-304) dated April 1981.

5-8 Radial Diffuser Fan for Surface Effect Ships, Report No. 101-82-2, Aerophysics, Washington, D.C.

6-1 Swanek, A., and J. Sikora, "SWATH Primary Structure: Design Considerations and Stress Calculation Method," Structures Department Technical Note, m52, April 1982.

6-2 Walz, R., D. Harry, N. Nappi and C. Wiernicki, "Structural Synthesis Design Program - MOD II/III," Structures Department Technical Note, August 1981.

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APPENDIX 1

DESIGN DESCRIPTION - WHEC-SES

1. INTRODUCTION

This appendix provides a description of a surface effect ship design concept developed to meet the requirements of the existing USCG-WHEC craft. The design concept is described in terms of layout drawings, tables, and text.

2. PRINCIPAL CHARACTERISTICS

The principal characteristics of the WHEC-SES are summarized in Table 1.2-1.

3. MISSION REQUIREMENTS

The mission requirements are summarized in Table 1.3-1.

4. SHIP CONFIGURATION

The WHEC-SES outboard profile and hull geometry are shown in Figures 1.4-1 and 1.4-2, respectively. The principal features of the major subsystems are discussed in the following paragraphs.

4.1 GENERAL ARRANGEMENT -- The general arrangement of the WHEC-SES is shown in Figure 1.4-3. As shown in Figure 1.4-3, the living spaces for all CPO and enlisted personnel, together with ship's offices, medical and major electronic equipment, are accommodated on the Second Deck level. Longitudinal passageways, port and starboard, and frequently spaced transverse passageways, provide unobstructed access for ship operation and damage control.

Table 1.2-1. WHEC-SES - Principal Characteristics

Length Overall	300 Ft - 0 In
Length Cushion	269 Ft - 0 In
Breadth Overall	68 Ft - 0 In
Breadth Cushion	39 Ft - 0 In
Depth Main Deck	34 Ft - 0 In
Depth Cushion	22 Ft - 0 In
Full Load Displacement	2100 Long Tons
Cruising Speed (Maximum Continuous Power and SS 0)	30 Knots
Propulsion Machinery	(High Speed) Two General Electric LM 2500 Gas Turbines
	(Low Speed) Two SACM 20V195RVR Diesel Engines
Propellers	Two Propellers
Lift Engines	Four SACM 20V195RVR Diesel Engines
Lift Fans	Eight Mixed Flow
Accommodations:	
Officers	15
CPO's	12
Enlisted Personnel	142
Total	169

Table 1.3-1. WHEC Design Requirements

A. Missions:

ELT - Enforcement of Laws & Treaties	SAR - Search and Rescue
	MER - Marine Environmental Response
	MP - Military Preparedness
	MSA - Marine Science Activities

B. Mission Equipment:

76mm Otto Melara w/MK 92 GFCS & ammo (10 Ltons)	Stores (25.6 Ltons)
(2) 6M RHI w/SPD (6.6 Ltons-(2)-19'x8'x4')	Water (28.5 Ltons)
An/SPS 40B Air Search Radar	Crew (42.4 Ltons)
Helo Fuel (60 HRS 16 Ltons)	CIWS (Vulcan Phalanx)
(2) 50 cal MG w/mounts and ammo (.5 Ltons)	LAMPS I
(2) 40mm MG w/mounts and ammo (.5 Ltons)	Active/Passive Sonar (Towed Array)
C^3 and Navigation (20 Ltons)	SLQ-32
CP Propellers	SRBOC

C. Speed vs. Sea State:

30 kts/Calm Water	25 kts/SS3
28 kts/SS2	20 kts/SS4

D. Endurance:

45 days — 16,900 NM Range (Economical Cruise Speed)
3,400 NM @ 30 kts with 10% reserve fuel

E. N/A - to be governed by (D.)

F. Operating Environment:

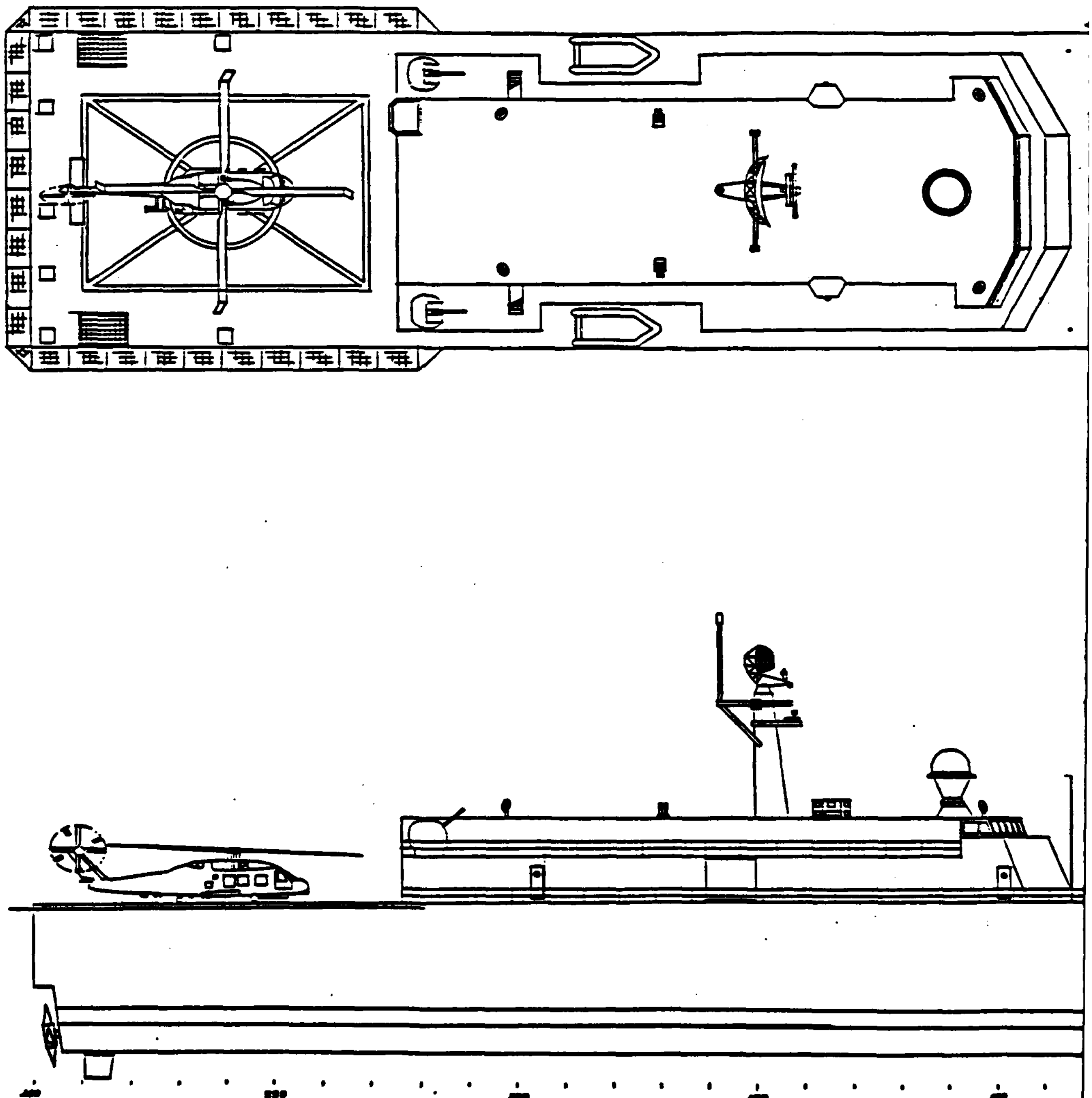
Worldwide (no ice capability)

G. Complement:

169 Permanent Crew — 15-Officers, 12-CPOs, 142-Enlisted

H. Other Design Features:

1. Refueling and replenishment at-sea
2. HH-52A and HH-65A operations and hanger capable
3. Rudder roll stabilization
4. External firefighting capabilities
5. Medical Support
6. HIFR
7. Meet USN 100 kt wind heel criteria
8. Survivability in SS6
9. 15-Yr hull life (aluminum or steel construction)
10. Expect 80% operation on-cushion



1

2

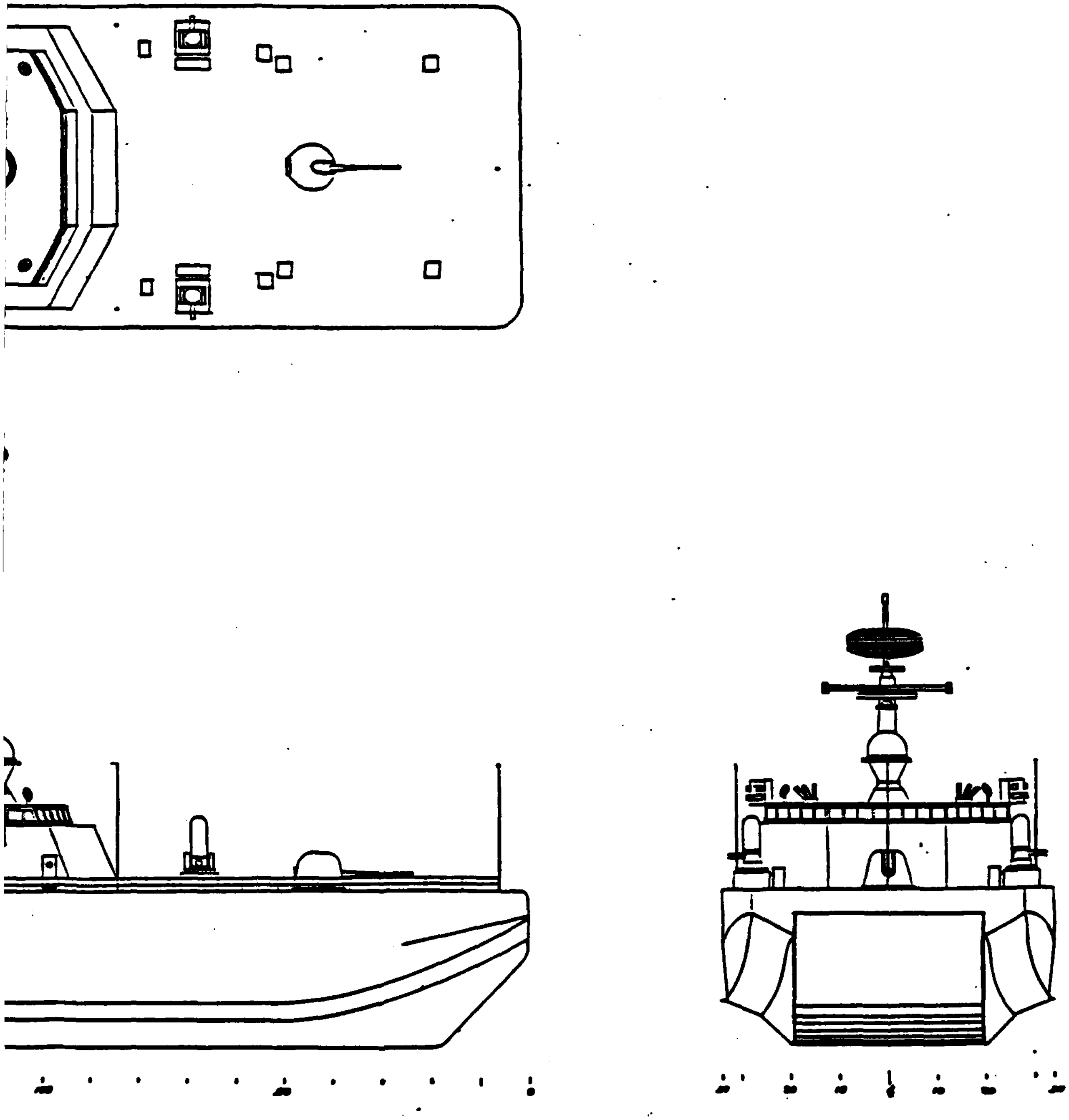
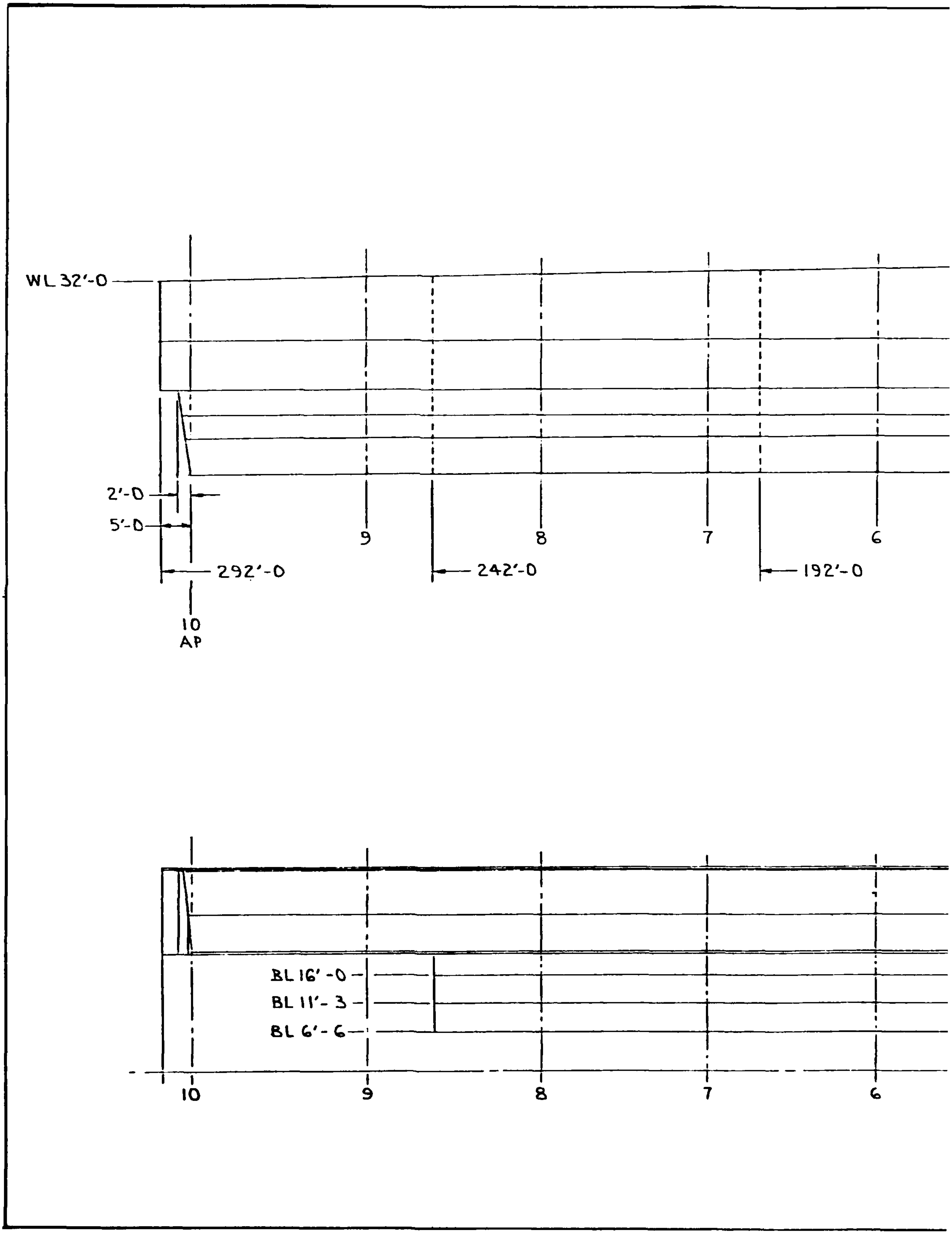


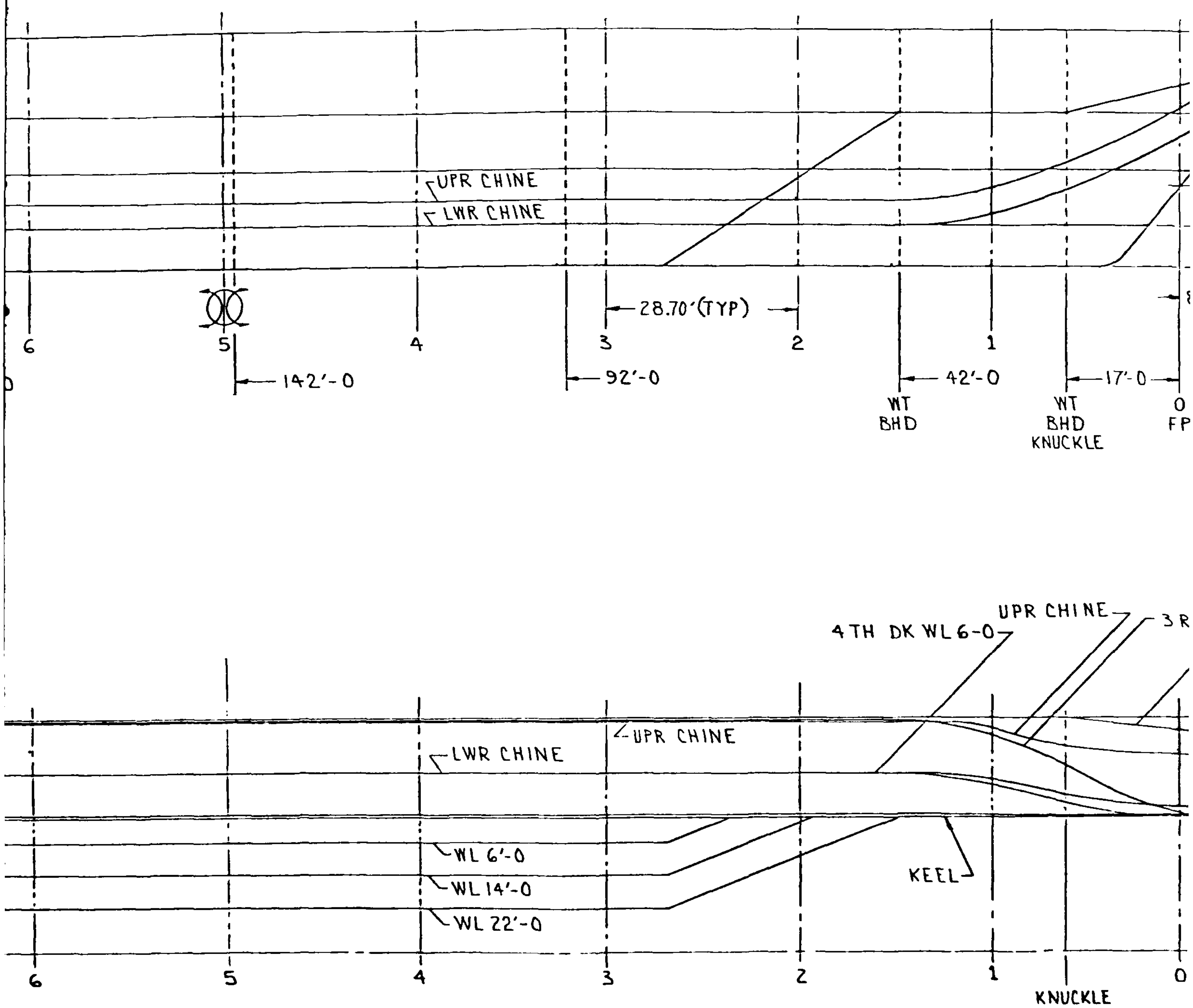
Figure 1.4-1. WHEC-SES
Outboard Profile



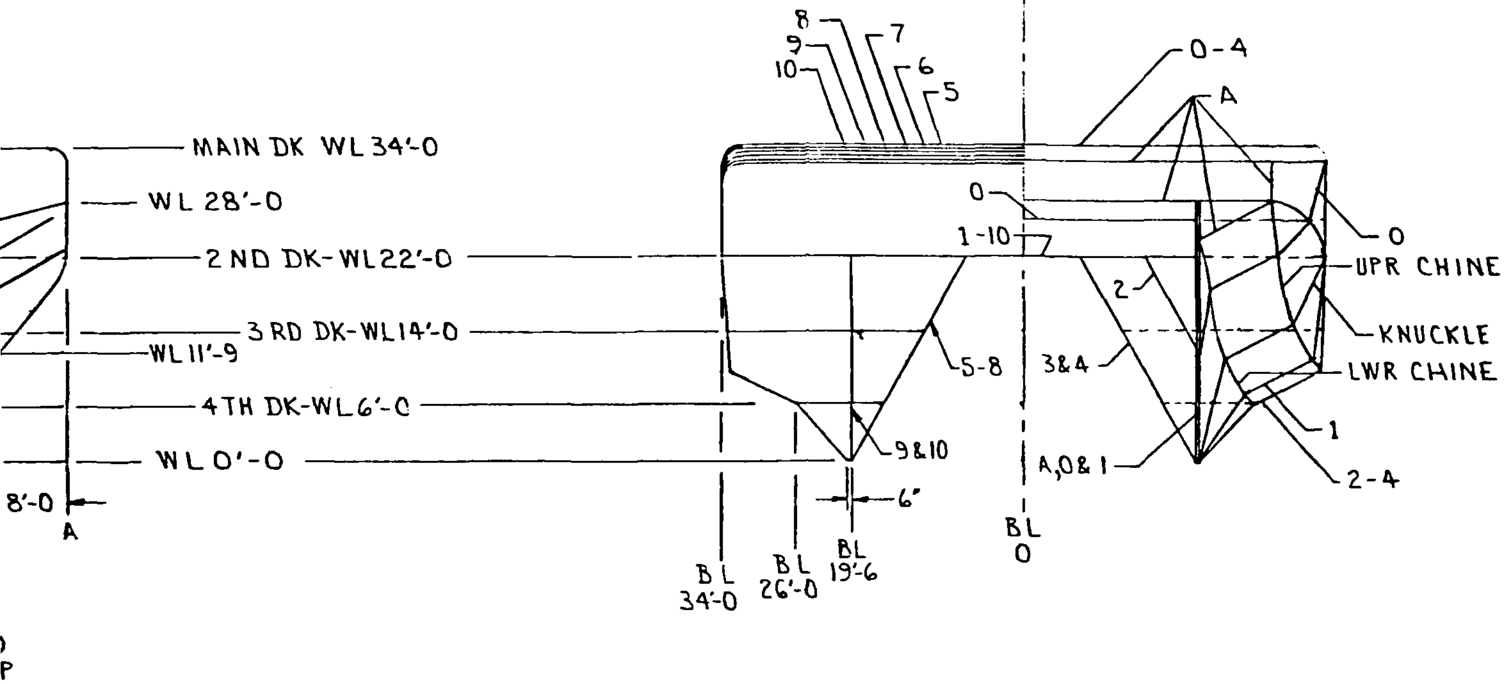
WL 32'-0
2'-0
5'-0
292'-0
242'-0
192'-0
9
8
7
6
10
AP
BL 16'-0
BL 11'-3
BL 6'-6
10
9
8
7
6

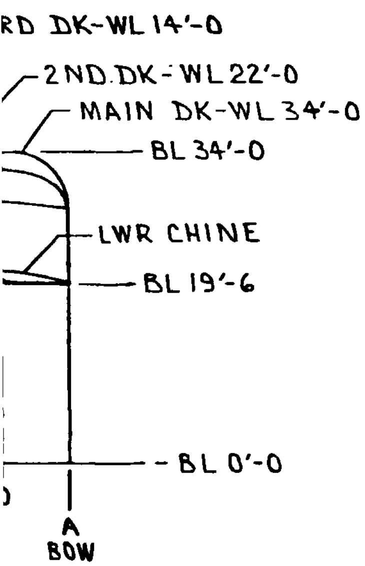
1

2



UPR CHINE
LWR CHINE
28.70'(TYP)
6
5
4
3
2
1
142'-0
92'-0
42'-0
17'-0
WT
BHD
WT
BHD
KNUCKLE
0
FP
UPR CHINE
4TH DK WL 6-0
UPR CHINE
LWR CHINE
WL 6'-0
WL 14'-0
WL 22'-0
KEEL
6
5
4
3
2
1
0
KNUCKLE

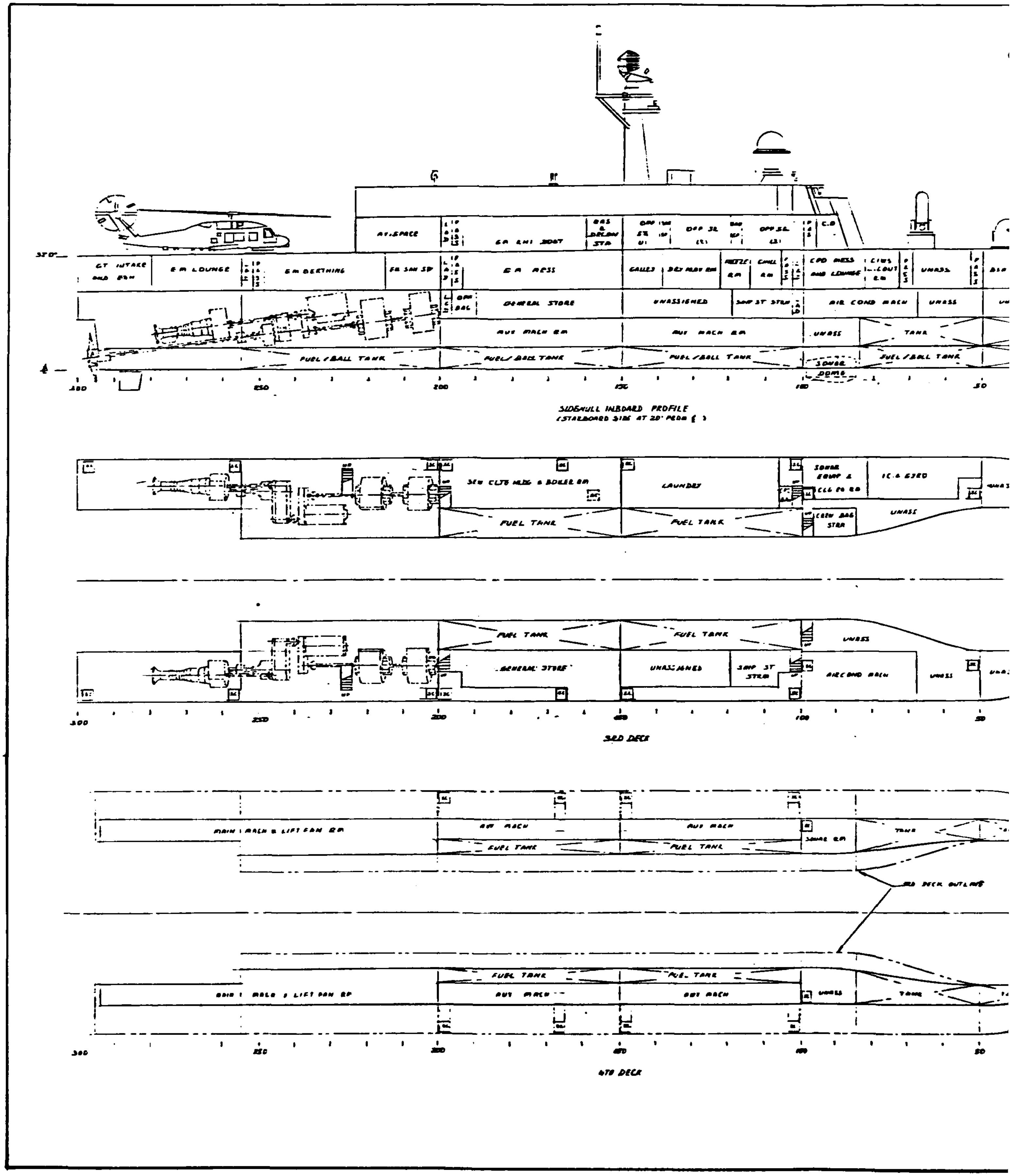




PRINCIPAL PARTICULARS

LENGTH OVERALL	300'-0
LENGTH B. P.	287'-0
BEAM MOLDED	68'-0
CUSHION LENGTH	269'-0
CUSHION BEAM	39'-0
CUSHION DEPTH	22'-0
DEPTH TO MAIN DECK	34'-0
DESIGN DISPLACEMENT	2100 L TONS
DRAFT HULLBORNE	11'-9

Figure 1.4-2. WHEC-SES Hull Lines

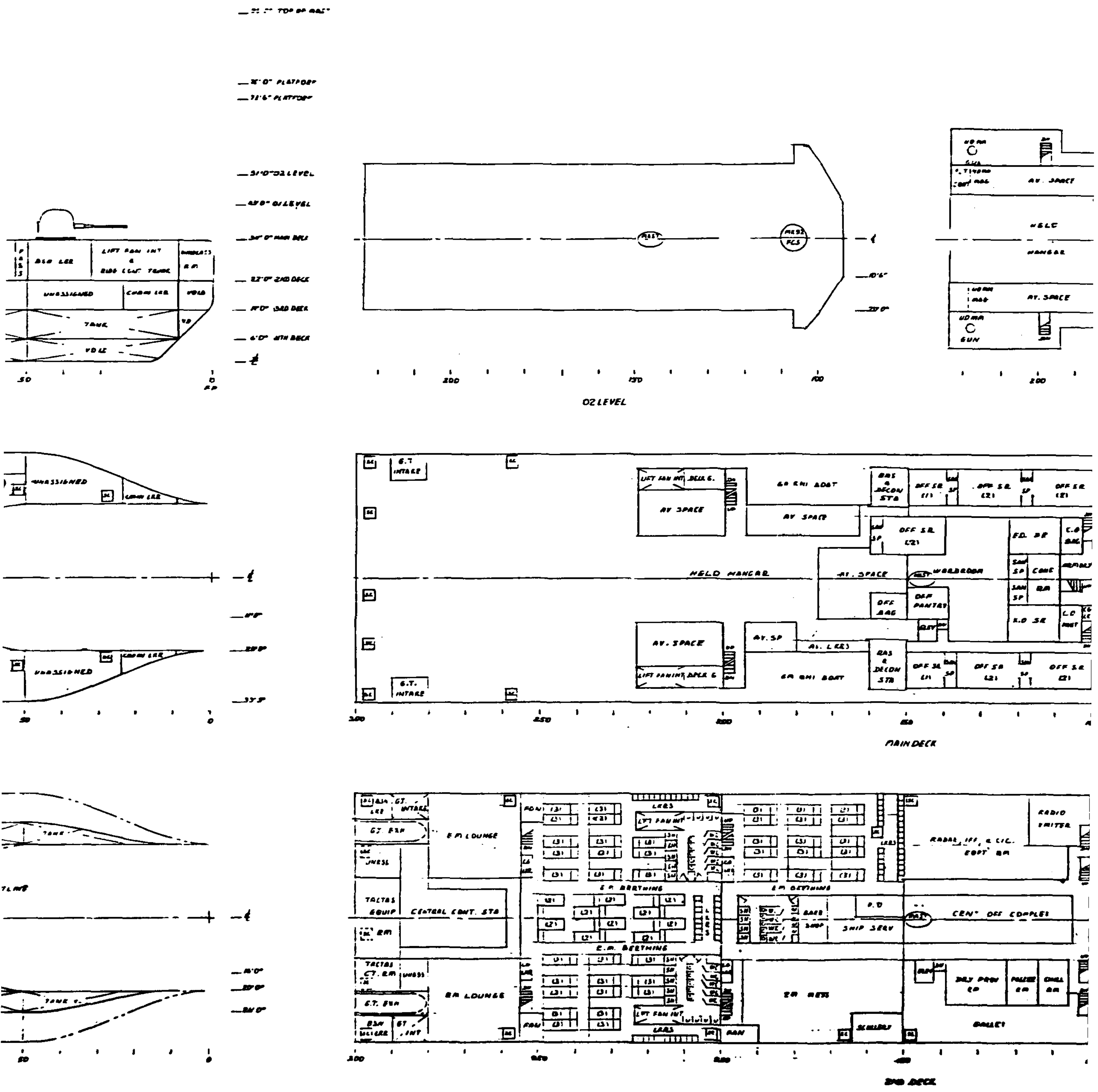


SIDEHULL INBOARD PROFILE
(STARBOARD SIDE AT 20' PEDG ℄)

3RD DECK

4TH DECK

2



O2 LEVEL
MAIN DECK
2ND DECK
HELO HANGAR
AV. SPACE
OFF SR (2)
WARDROOM
OFF PANTRY
G.T. INTAKE
LIFT FAN INT. DECK 6
E.M. BERTHING
EM LOUNGE
CENTRAL CONT. STA
SHIP SERV
EM MESS
SCULLERY
GALLEY
CENT OFF COMPLEX
UNASSIGNED
TANK
VOID
MAST
MAST FCS

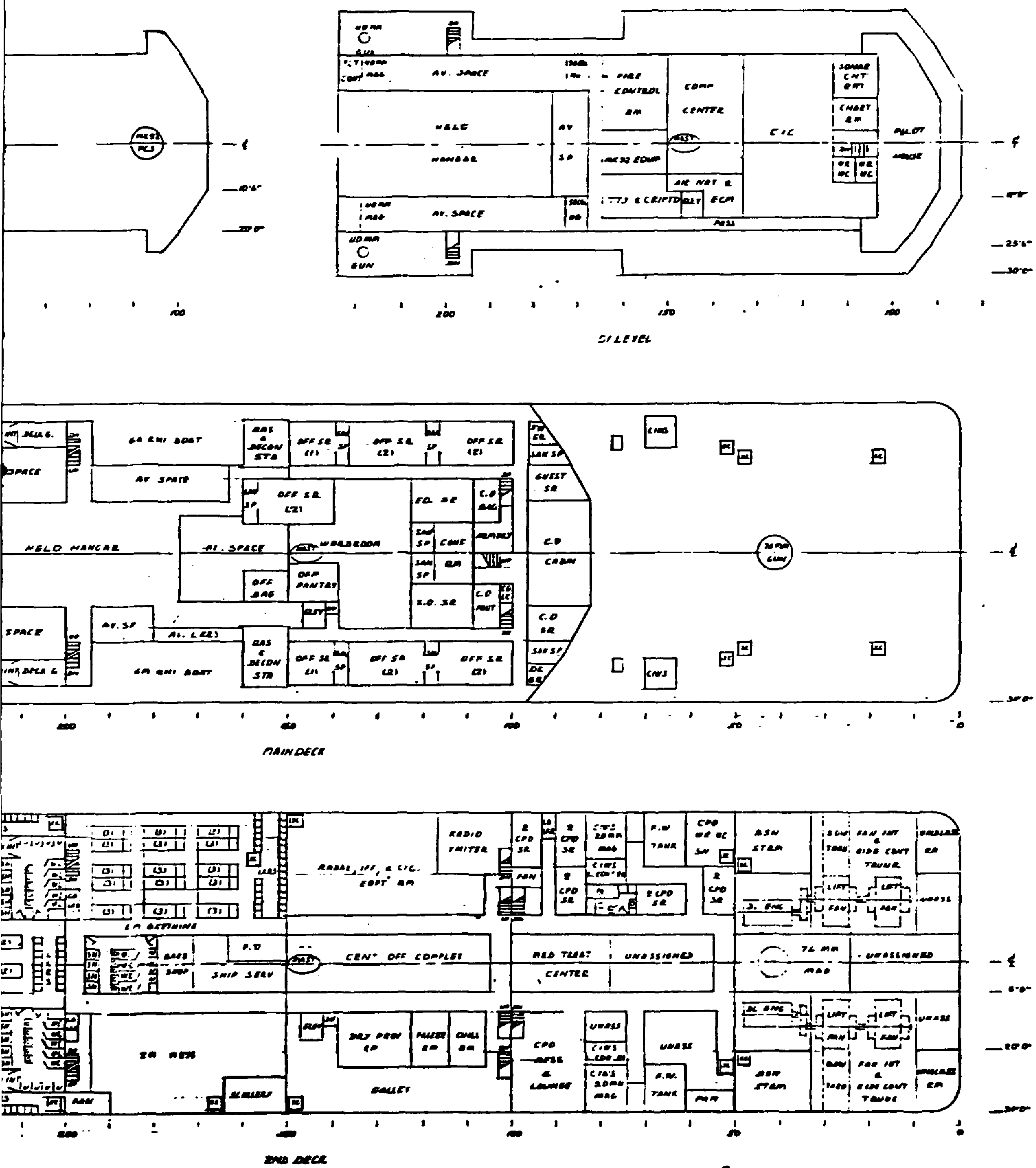


Figure 1.4-3. WHEC-SES General Arrangement

Living spaces for officer personnel, together with the helo platform, hangar, and aviation support spaces, are provided on the Main Deck level. Two CIWS installations and one 76mm gun installation are provided on the forward weather area of the Main Deck.

The pilothouse, CIC, communication center and other communication spaces are located on the 01 level immediately above the officer's living spaces. Additional aviation support spaces in the hangar area and two 40mm guns, arranged port and starboard, are provided on the 01 level.

Deck area allocations and other hull volume allocations are summarized in Table 1.4-1. For comparison, the space allocations provided in the existing 378-foot WHEC class ship are also shown in Table 1.4-1.

4.2 HULL STRUCTURE -- The hull is constructed of all-welded, high strength, low alloy steel. The structural arrangement is shown in Figure 1.4-4. The structural design criteria and the shear and bending moment envelopes derived for the structural design are shown in Figures 1.4-5 and 1.4-6, respectively.

4.3 MACHINERY ARRANGEMENT -- The arrangement of the propulsion and lift machinery is shown in Figure 1.4-7. As shown in Figure 1.4-7, the propulsion engines, aft lift engines, and aft lift fans are located port and starboard in the sidehull regions aft. The forward lift engines and fans are located on the forward region of the second deck. The arrangement shown was selected to provide the maximum isolation of the machinery from habitability spaces within the constraints of ship size and other arrangement requirements. The machinery isolation provided by the arrangement, coupled with the installation of vibration isolation mounts for all machinery and acoustical treatment on machinery space boundaries, should ensure low levels of noise and vibration in all habitability spaces.

The cushion seal installation consists of a transversely stiffened membrane (TSM) bow seal and a multiple loop bag stern seal. Both bow and stern

Table 1.4-1. WHEC-SES - Deck Area and Hull Volume Allocations

	SPACE DESCRIPTION	WHEC-SES		EXISTING CRAFT			
				378 FT WHEC			
		FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
BERTHING	CO (and Guest)	180	90	176	88		
	XO	140	140	121	121		
	EO	140	140	121	121		
	Officer (1 Person Stateroom)	100	100	88	88		
	Officer (2 Person Stateroom)	170	85	124	62		
	CPO	462	38.5	554	46.2		
	EM	3408	24	3328	23.4		
SANITARY	CO (and Guest)	85		68			
	XO	35		32			
	EO	35		32			
	Officer (1)	30		33			
	Officer (2)	30		38.5			
	CPO	126		81			
	EM	741		665			
MESS	CO (Cabin/Office)	336		340			
	Ward Room	707		587			
	CPO Mess CPO Lounge	382		375			
	EM Mess	868.1		870			
	EM Lounge	1150		1115			
COMMISSARY	CO Pantry	60		52			
	Officer Pantry	82		96			
	Galley	621		448			
	Scullery	112		90			
	Chill	106		175			
	Freeze	106		135			
	Dry Provisions	200		192			
	Ship Service	546		300			
	Barber Shop	110		60			
	PO	78		19			
	Ship Service Storeroom Supply Storeroom Small Stores ET Stores WR Stores	692		539			
	Sea Bag Storage	187		76			
	(Continued on next page)						

Table 1.4-1. WHEC-SES - Deck Area and Hull Volume Allocations (Cont'd.)

	SPACE DESCRIPTION	WHEC-SES		EXISTING CRAFT			
				378 FT WHEC			
		FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
MED.	Medical Facility	286		240			
	TOTAL	12311		11170.5			
	Pilothouse	530		440			
	Chart Room	370		30			
	CIC	815		460			
	Communication Center	459		462			
	Radio Transmitter	220		-			
	Sonar Room	100		85			
	Fire Control Room	238		272			
	MK92 Equipment Room	140		-			
	TTY and Cripto	157		173			
	Air NAV and ECM	122		68			
	TACTAS Control Room	108		-			
	TACTAS Equipment Room	264		-			
	Radar, IFF & CIC Equipment Room	1070		654			
	IC and Gyro	342		313			
	Sonar Equipment Room	204		192			
	CIWS Control Room	108		-			
	Helo Control Station	40		-			
	Central Control Station	558		280			
	TOTAL	5845		3429			
	511-38 Magazine	-		216			
	76mm Magazine	338		-			
	20-40mm Magazine	104		168			
	50 Cal. Magazine	80		40			
	Small Arms Magazine Armory	75		32			
	CIWS Magazine	189		-			
	Helo Hangar	1152		-			
	Aviation Space (Off., Store, Shops, etc.)	2196		40			
	Torpedo Storage	-		95			
	TOTAL	4134		591			
	Unassigned	2500					

Table 1.4-1. WHEC-SES - Deck Area and Hull Volume Allocations (Cont'd.)

SPACE DESCRIPTION	WHEC-SES		EXISTING CRAFT			
			378 FT WHEC			
	FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN

OTHER EQUIPMENT:

Water

Required = 28.5 Tons
Available = 45.6 Tons

Fuel

Required* = 804 + 16 = 820 Tons
Available
Tanks (1 & 2) = 74 x .95 x .98 = 68.9 Tons
Tanks (3 & 4) = 79 x .95 x .98 = 73.5 Tons
Tanks (5 & 6) = 45 x .95 x .98 = 42.2 Tons
Tanks (7 - 12) = 202 x .95 x .98 = 188 Tons
Tanks (13 - 16) = 548 x .95 x .98= 510.2 Tons

TOTAL 882.8 Tons

* The values given are ship and helo fuel estimates (Figure 4.2-1.)

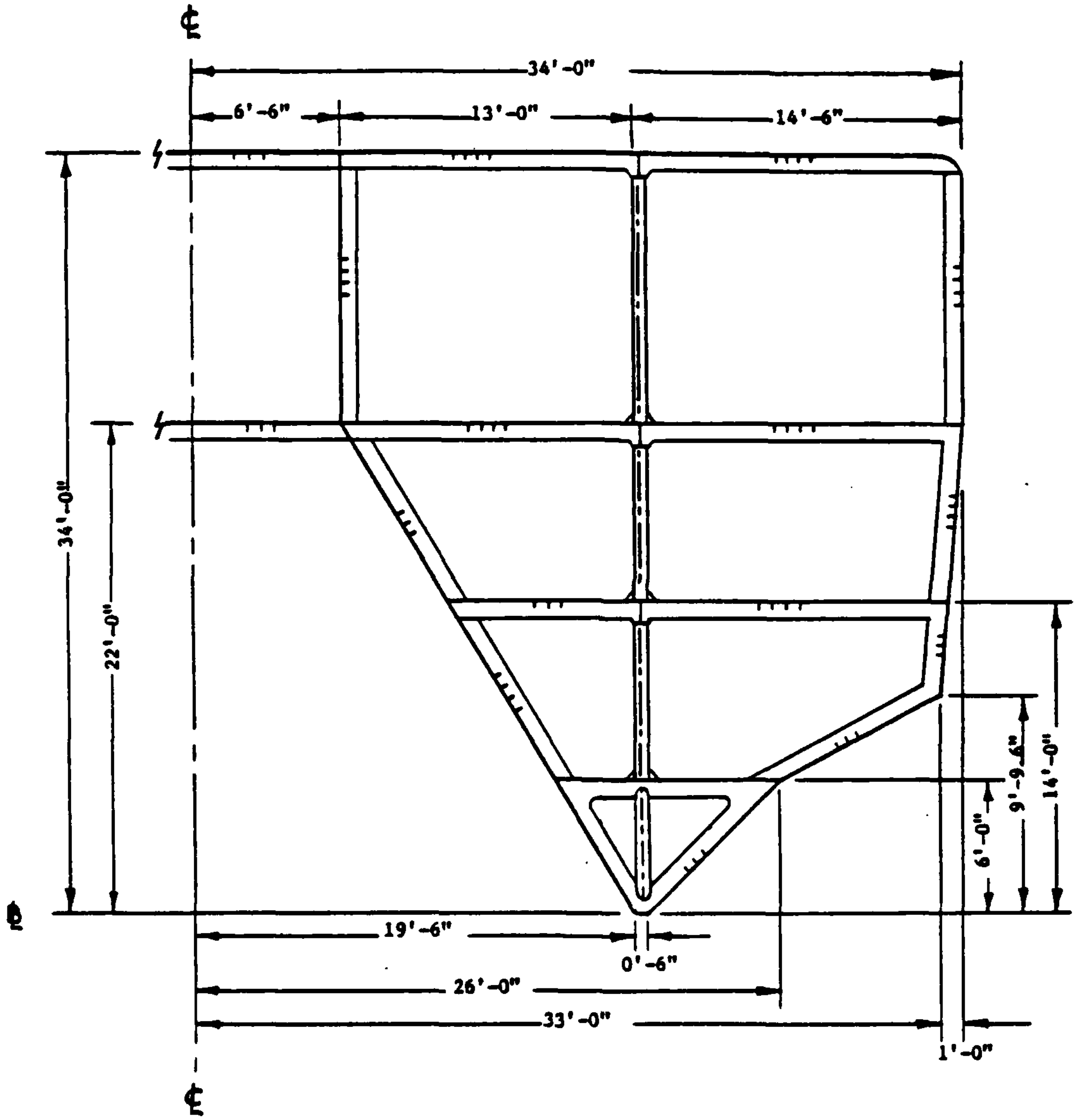


Figure 1.4-4. WHEC-SES - Typical Midship Frame Section

SLAM PRESSURES ARE <u>NOT</u> COMBINED
WITH HULL GIRDER LOADS

LOCAL LOADS (OTHER THAN
SLAMMING) <u>ARE</u> COMBINED WITH
HULL GIRDER LOADS

LOCAL LOADS INCLUDE DECK
LIVE LOADS: 75 PSF (TOP OF DK HSE)
150 PSF (LIVING, OFFICE SPACES)
200 PSF (MACHINERY SPACES)

USE 50% OF SLAM PRESSURE FOR FRAME DESIGN

SAFETY FACTORS	YIELD	ULT.
HULLBORNE + LOCAL LOADS	1.2	1.5
CUSHIONBORNE + LOCAL LOADS	1.2	1.5
*SLAMMING PRESSURES	1.0	1.2

*PERMANENT SET TO
A MAXIMUM OF PLATE
THICKNESS IS ALLOWED

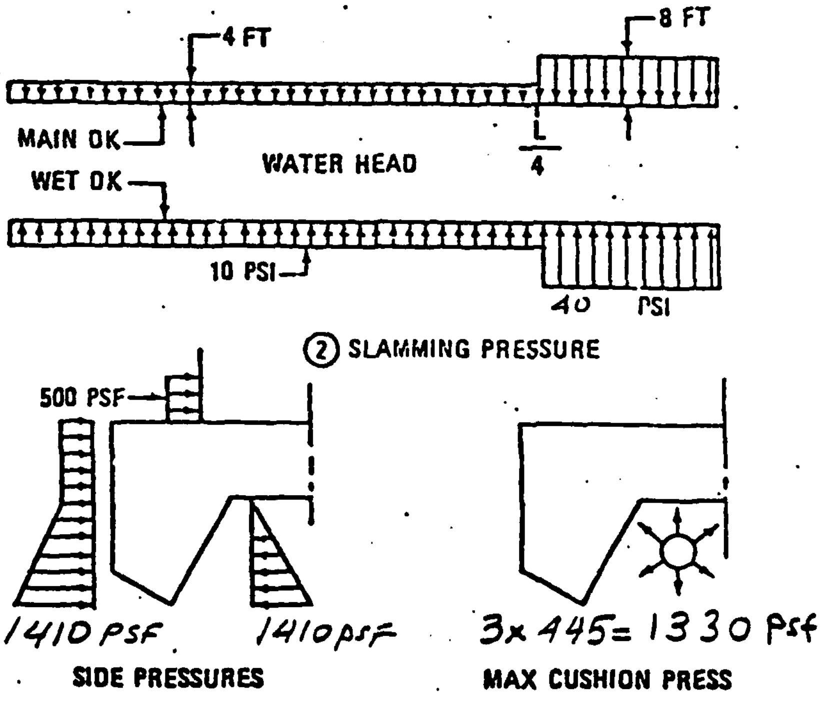
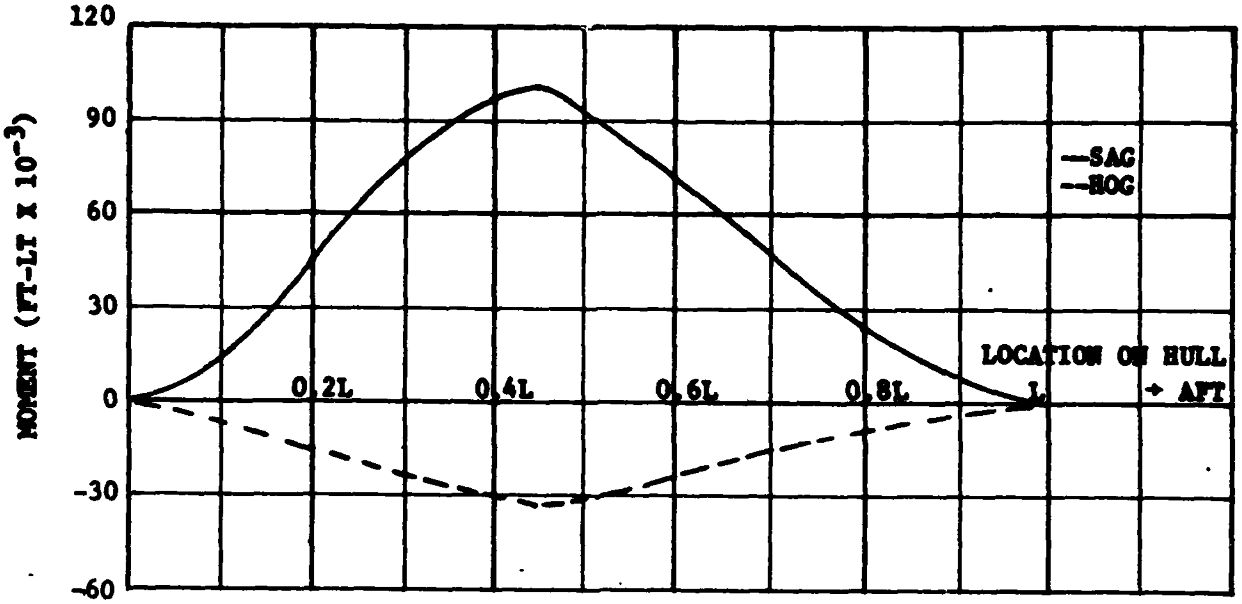
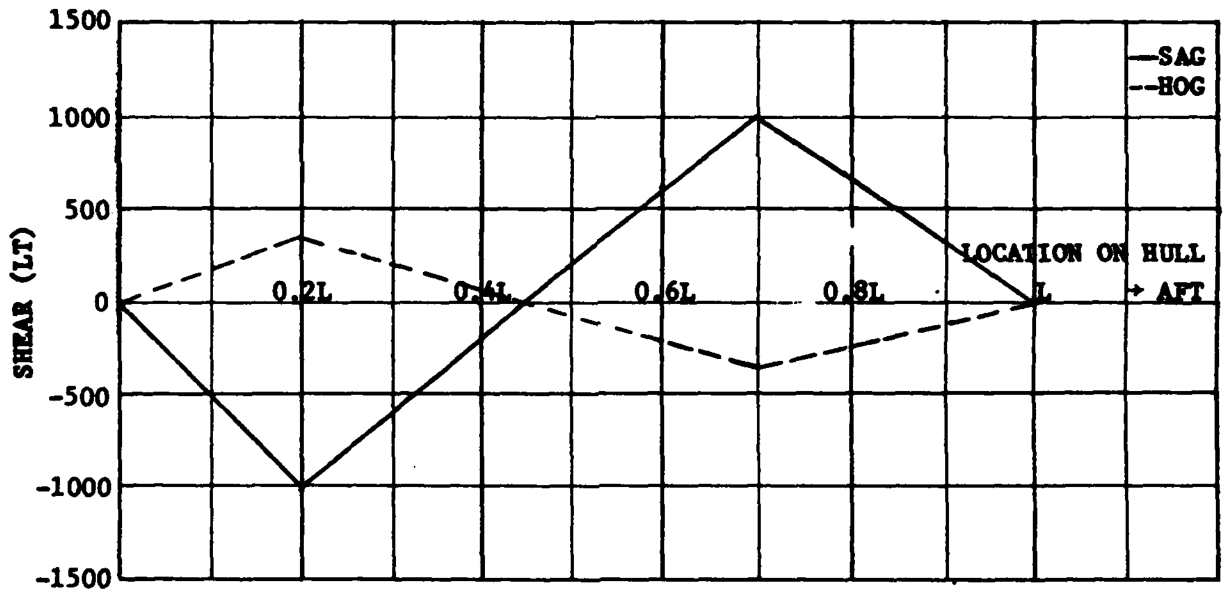


Figure 1.4-5. WHEC-SES Hull Design Criteria



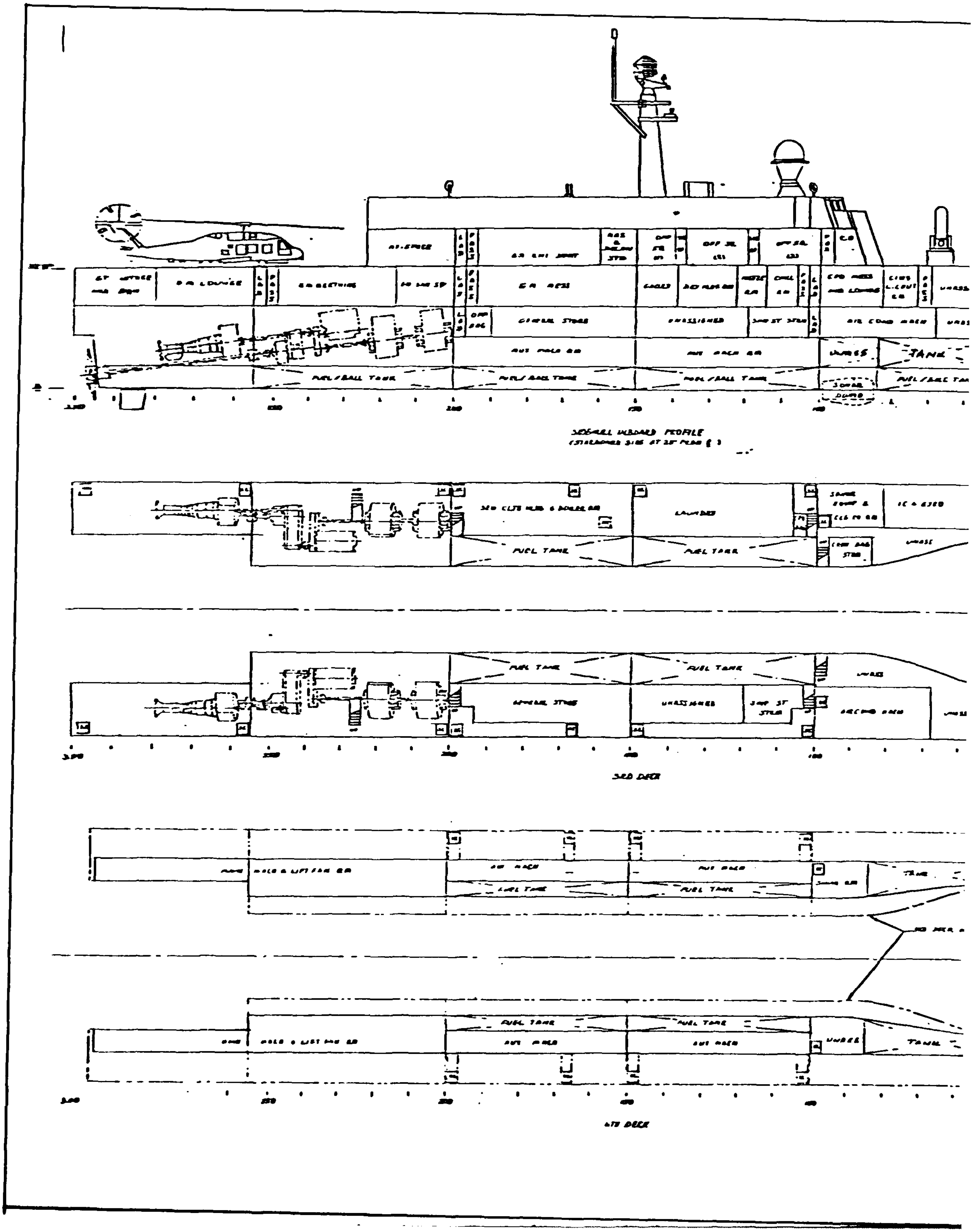
HULLBORNE BENDING MOMENT



HULLBORNE SHEAR

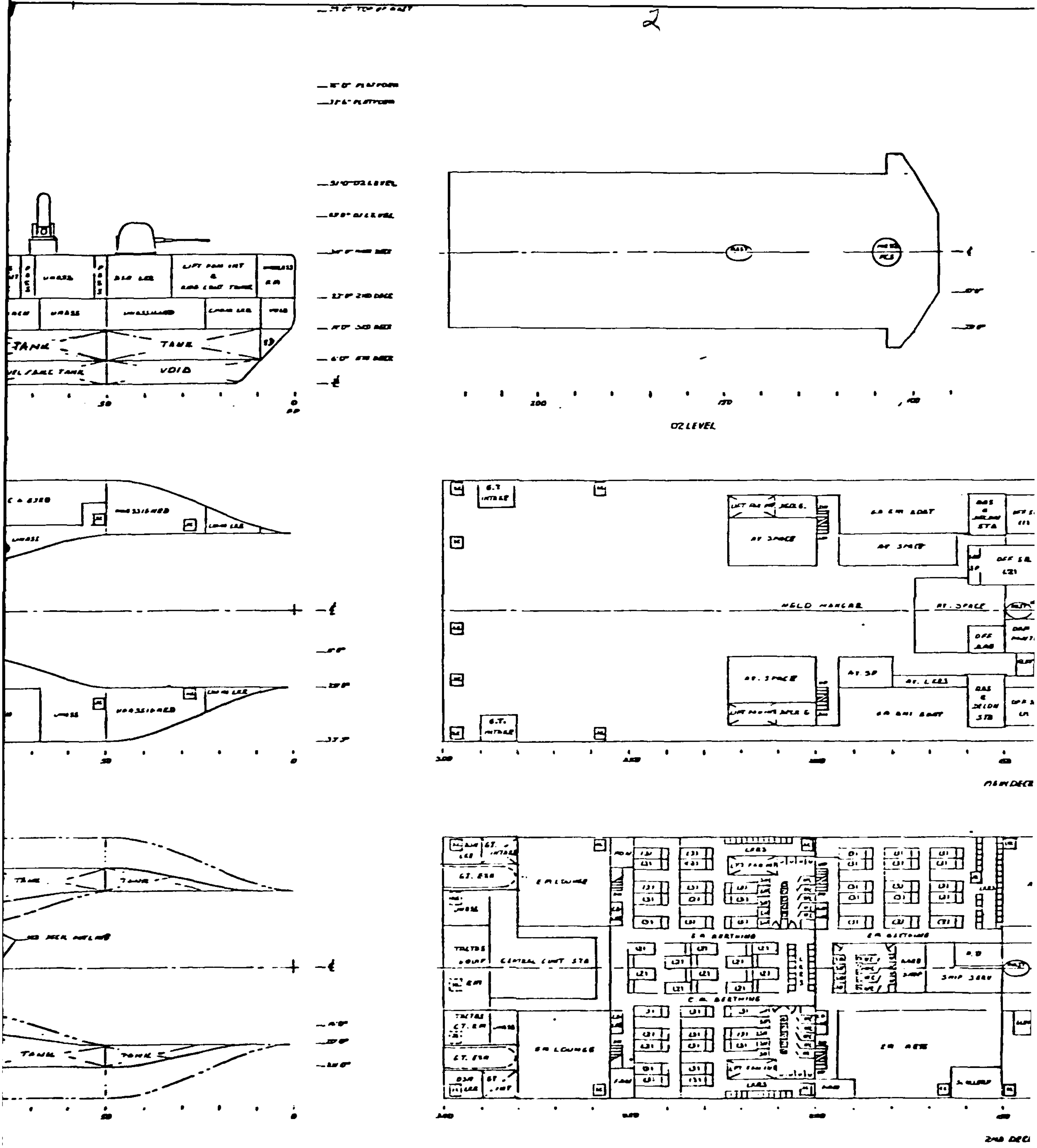
Safety Factor - SF Yield = 1.2
SF ULT = 1.5

Figure 1.4-6. WHEC-SES Design Shear and Bending Moment Envelopes


SEAGULL INBOARD PROFILE
3RD DECK
GENERAL STORE
FUEL TANK
LAUNDRY
UNASSIGNED

1

2



TANK
VOID
02 LEVEL
HELO HANGAR
AV. SPACE
MAIN DECK
E.M. LOUNGE
CENTRAL CONT STA
E.M. BERTHING
C.M. BERTHING
SHIP SERV
2ND DECK

1

3

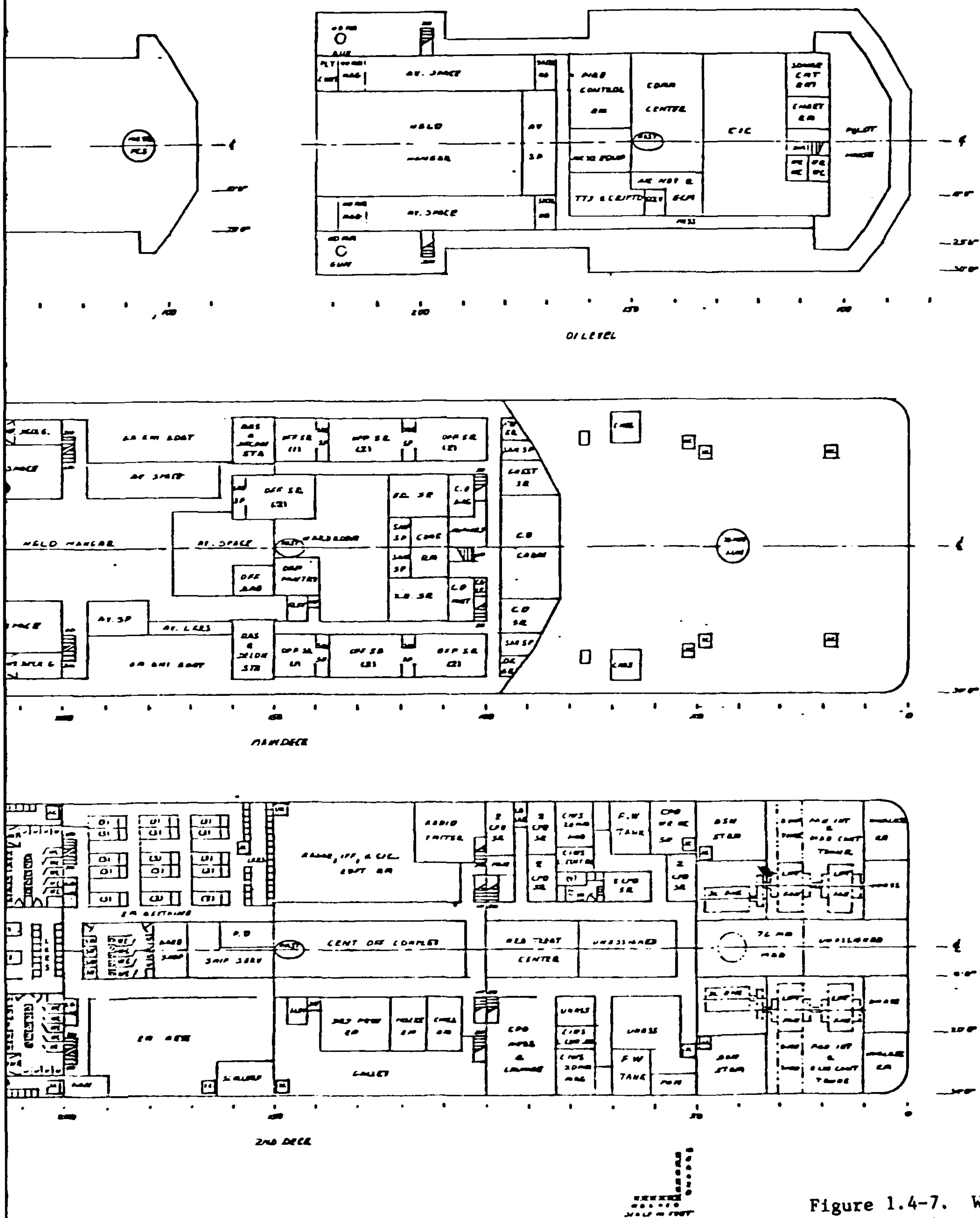


Figure 1.4-7. WHEC-SES Machinery Arrangement

AD-A158 200   CONCEPTUAL DESIGN OF FOUR SURFACE EFFECT SHIPS FOR US COAST GUARD APPLICATIONS(U) COAST GUARD WASHINGTON DC OFFICE OF RESEARCH AND DEVELOPMENT   MAY 85 USCG-D-13-85

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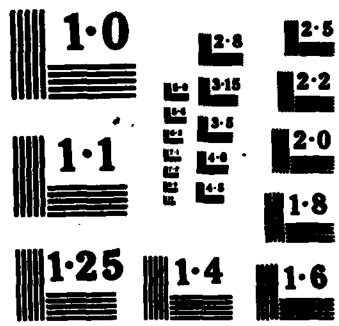
UNCLASSIFIED   F/G 13/10   NL


1·0
2·8
2·5
3·15
2·2
3·5
1·1
4·0
2·0
4·5
1·8
1·25
1·4
1·6

seals are provided with retraction systems. The bow seal and stern seal are shown in Figures 1.4-8 and 1.4-9, respectively. The seal materials are listed in Table 1.4-2.

4.4 ELECTRICAL SYSTEM -- The electrical power system consists of three 500 KW, 60 Hz diesel generators connected in a ring bus distribution system. The power provided by the two operating diesel engines is adequate to satisfy the ship's electrical power requirements under all operating conditions. The third generator provides standby power. Transformer rectifiers of a type proven in service aboard Navy ships are used to provide 28 volt DC for control and actuator power, as required. A battery bank is used to provide emergency and/or uninterruptible power. Two solid state 60 Hz/400 H2 frequency convertors are employed to provide 400 Hz power as required with one operational and the other on standby under normal operating conditions. A diagram of the electrical power distribution concept is shown in Figure 1.4-10.

4.5 COMMAND COMMUNICATION AND CONTROL -- Three principal command, communication and control spaces are provided:

1. Pilot House located on the 01 level.
2. CIC located on the 01 level.
3. Central Control located aft on the Second Deck.

The Pilot House serves as the primary control station for ship maneuvering, navigation and collision avoidance. Limited control of propulsion and lift machinery is provided in the Pilot House to the extent required for ship handling.

The CIC serves as the center for tactical command and is supported by dedicated spaces for communication, TTY and Crypto, fire control and air navigation.

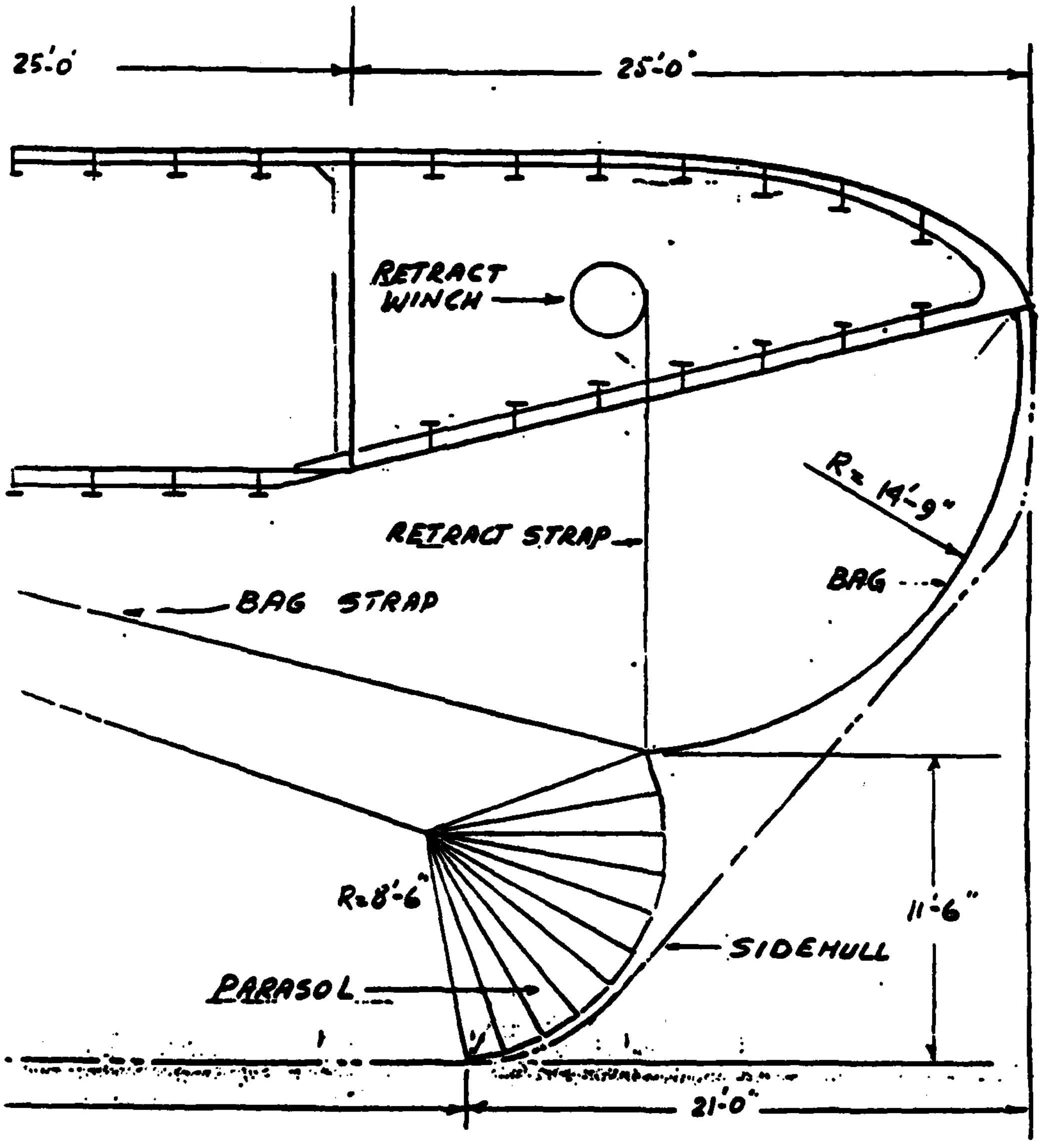


Figure 1.4-8. WHEC-SES Bow Seal

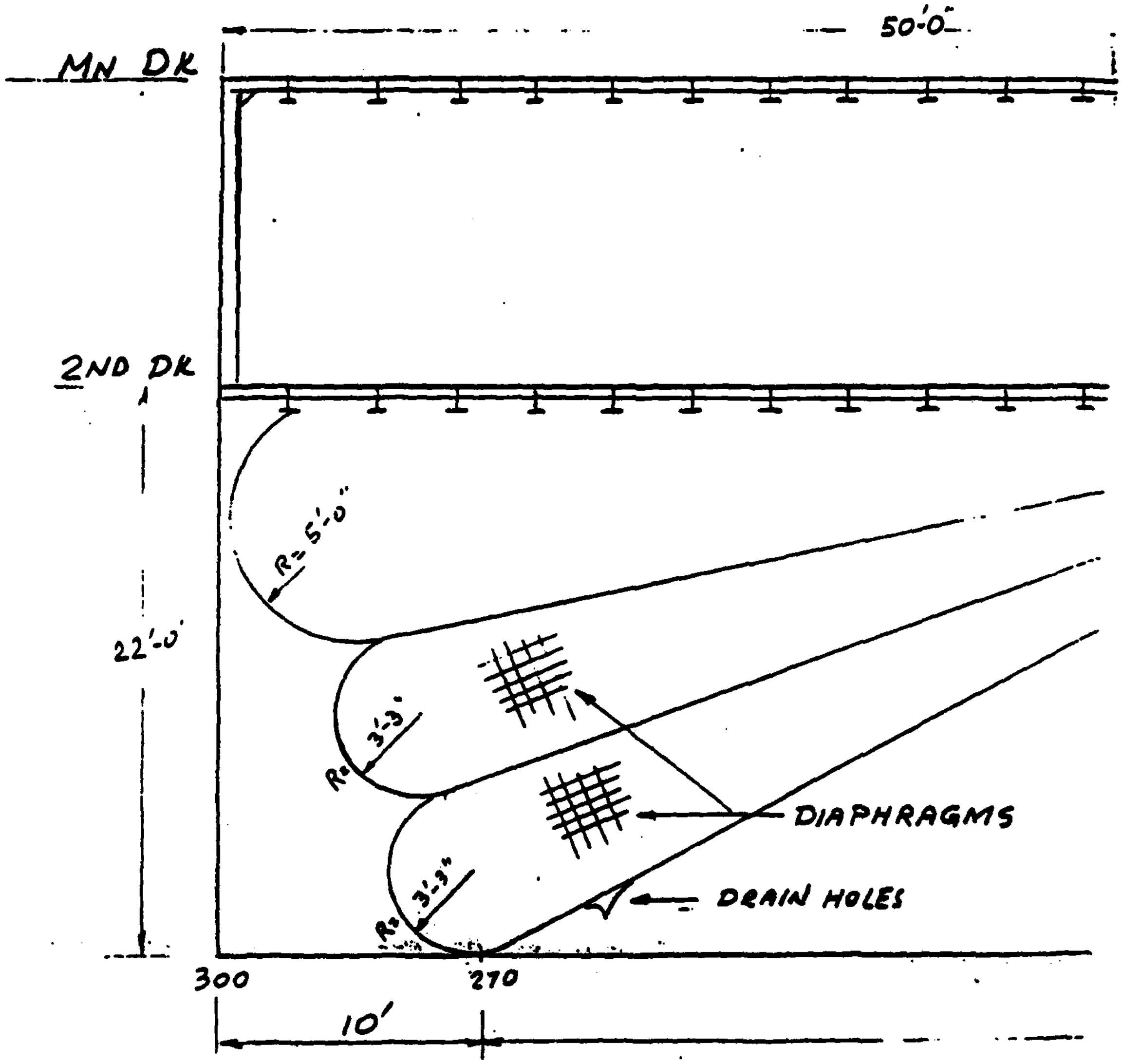


Figure 1.4-9. WHEC-SES Stern Seal

Table 1.4-2. WHEC-SES Seal Materials

MATERIAL CHARACTERISTIC	BAG		PARASOL (NOTE (1))
	BOW	STERN	
Fabric Type	Nylon 3x3 (Basket Weave)	Nylon 3x3 (Basket Weave)	Nylon 3x3 (Basket Weave)
Coating Type	Neoprene Base Rubber	Neoprene Base Rubber	Neoprene Base Rubber
Material Weight	170 Oz/Yd^2	90 Oz/Yd^2	90 Oz/Yd^2
Tensile Strength { Warp	3000 pli	1240 pli	1240 pli
Tensile Strength { Fill	3000 pli	1280 pli	1280 pli
Minimum Tear Strength	>500 pli	>500 pli	>500 pli

Notes:

1. Parasol stiffening elements (battens) have the following dimensions:

   Thickness = 3/16 In. to 1/4 In.

   Width = 1 In. - 1-1/2 In.

   Length 18 In.

   The batten material is glass reinforced plastic (Scotchply 1002). Fibers are unidirectional and parallel to the long side of the batten. Batten material properties are as follows:

   Room Temp. and Dry:
   - Flexural Strength = 165,000 psi
   - Modulus in Flexure = 5.3×10^6 psi
   - Tensile Strength = 160,000 psi
   - Specific Gravity = 1.8

2. Alternate seal coating may be Chemigum vinyl (Goodyear M-521);fabric type may be Goodyear H391.

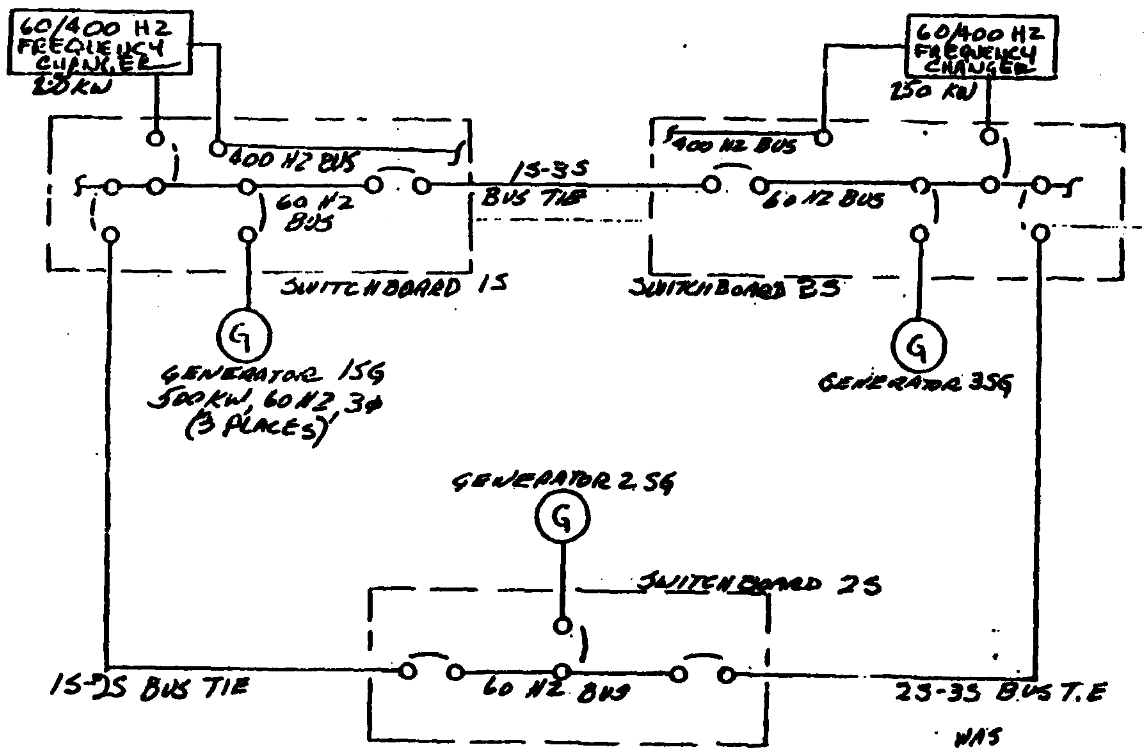


Figure 1.4-10. WHEC-SES Power System Distribution Diagram

The Central Control Room serves as the primary control station for all ship engineering and auxiliary support functions including control and monitor capability for propulsion, lift, electrical and auxiliary machinery and damage control.

A certain amount of commonality is necessary between the control system functions assigned to the Pilot House and the Central Control Room. Vital ship functions, such as propulsion/lift engine throttle control and communications capability, are duplicated between the two spaces for reliability and safety. Additionally, certain alarms are provided in the Pilot House, with functional control of the monitored equipment being assigned to the Central Control Room.

Redundancy is provided for vital functions with (1) control consoles in the Pilot House and the Control Center , (2) spatially separated dual remote control paths, and (3) local control.

Navigation equipment is listed in Table 1.4-3.

5. WEIGHT ESTIMATE

The weight estimate is summarized in Table 1-5.1. The lightship weights shown in Table 1.5-1 were derived from parametric analysis of other SES designs and the use of catalog information for major equipment items. Weights for mission related equipment and variable load items were derived from the design requirements defined in Section 3.

Table 1.4-3. WHEC-SES Command, Communication, and Control Equipment

CIC • AUTOMATED CIC (COMDAC) **FIRE CONTROL** • MK 92 GMS **SURVEILLANCE** • AN/SLQ-32 TOWED ARRAY SONAR	**NAVIGATION EQUIPMENT** • RADAR (COLLISION AVOIDANCE) (TWO SYSTEMS) • LORAN-C • SATNAV • RDF • GYRO • FATHOMETER • SPEED LOG • WIND SPEED AND DIRECTION	**COMMUNICATIONS EQUIPMENT** • VHF (TWO SYSTEMS) • SSB-HF (TWO SYSTEMS) • INTERIOR COMMUNICATION • INTERIOR TELEPHONE

Table 1.5-1. WHEC-SES Weight Estimate

SWBS	ITEM	LONG TONS
100	Hull Structure and Seals	522.0
200	Propulsion and Lift Systems	190.0
300	Electric Power Generation and Distribution System	42.0
400	Command and Surveillance System	58.0
500	Auxiliary Subsystems	73.0
600	Outfit and Furnishings	120.0
700	Combat System	30.0
	Estimated Lightship (without margin)	1035.0
	Design and Construction Margin (10%):	104.0
	Design Lightship	1139.0
F10	F10 - Personnel	42.4
F23	F23 - Ordnance Delivery Systems	6.0
F29	F29 - Mission Related Expendables	38.5
F30	F30 - Stores	25.6
F50	F50 - Liquids and Gases	28.5
F42	F42 - Helo Fuel	16.0
F42	F42 - Ships Fuel	804.0
	Full Load Displacement (FLD)	2100.0

6. PERFORMANCE

The performance characteristics in terms of power, speed, range, ride quality, hydrostatic characteristics and stability are summarized below.

6.1 SPEED, DRAG AND SEA STATE RELATIONSHIPS -- The speed, drag, and power relationships for cushionborne and hullborne operation at various craft displacements in Sea State 0 and Sea State 3 are shown in Figures 1.6-1 through 1.6-4.

6.2 RANGE CAPABILITY -- The range capability for 30-knot cushionborne and 9-knot hullborne operation in Sea State 0 is shown in Figure 1.6-5.

6.3 SHIP MOTIONS AND RIDE QUALITY -- The ship motions characteristics at various speed and sea states relative to the U. S. Navy 30-minute and 4-hour ride quality criteria are shown in Figures 1.6-6 through 1.6-8. Note that the characteristics shown are representative of head sea conditions. Some improvement in ride quality may be accomplished by adjustment of the ship's heading to avoid the head sea condition.

6.4 HYDROSTATIC CHARACTERISTICS -- The hydrostatic characteristics, as derived from the lines drawing shown in Figure 1.3-2 are presented in Figures 1.6-9 through 1.6-15.

6.5 INTACT STABILITY -- The intact stability characteristics in the full load condition and burned out condition are shown in Figures 1.6-16 and 1.6-17, respectively. As shown in the figures, the craft satisfies the intact stability criteria of DDS 079-1, "Stability and Buoyancy of U. S. Naval Surface Ships", in both conditions.

6.6 DAMAGE STABILITY -- The assessment of stability under various conditions of two compartment damage is shown in Figures 1.6-18 through 1.6-27. As shown, the craft satisfies the requirements of DDS 079-1 under all damage conditions investigated. The assessment was based upon on intact full load displacement condition. A permeability of ninety five percent was assumed for all areas subject to flooding.

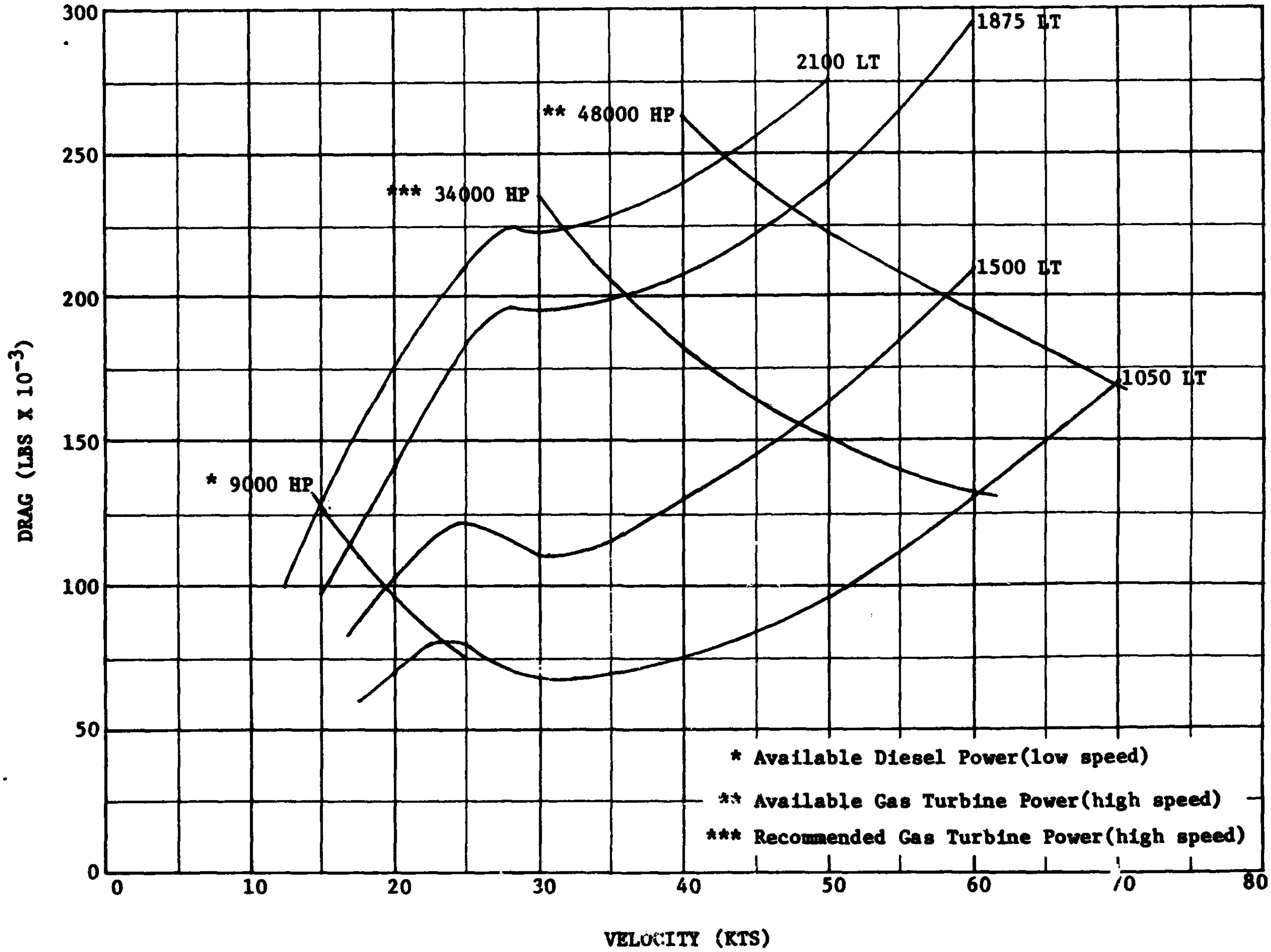


Figure 1.6-1. WHEC-SES Speed, Drag and Power Cushionborne - Sea State 0

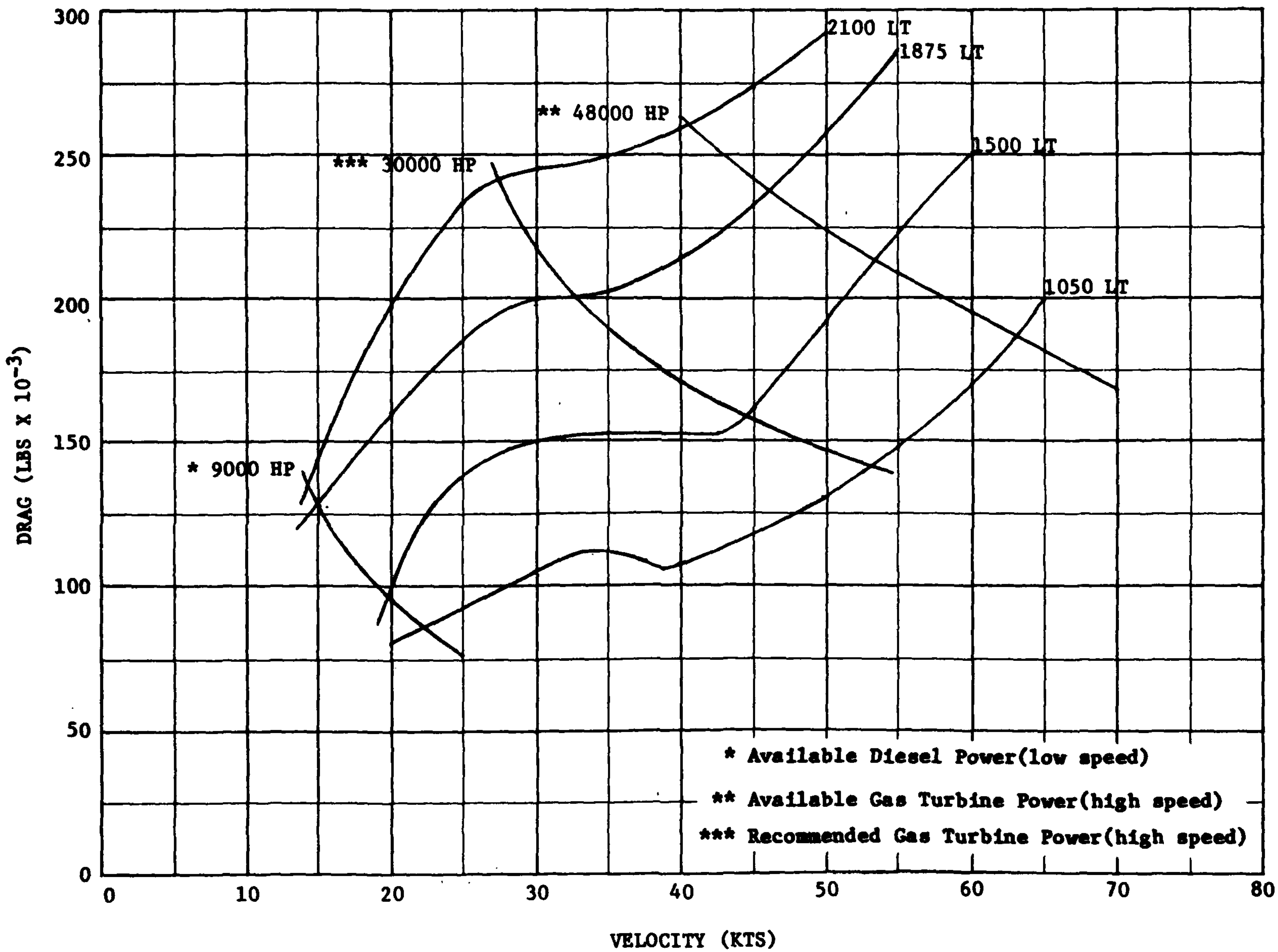


Figure 1.6-2. WHEC-SES Speed, Drag and Power Cushionborne - Sea State 3

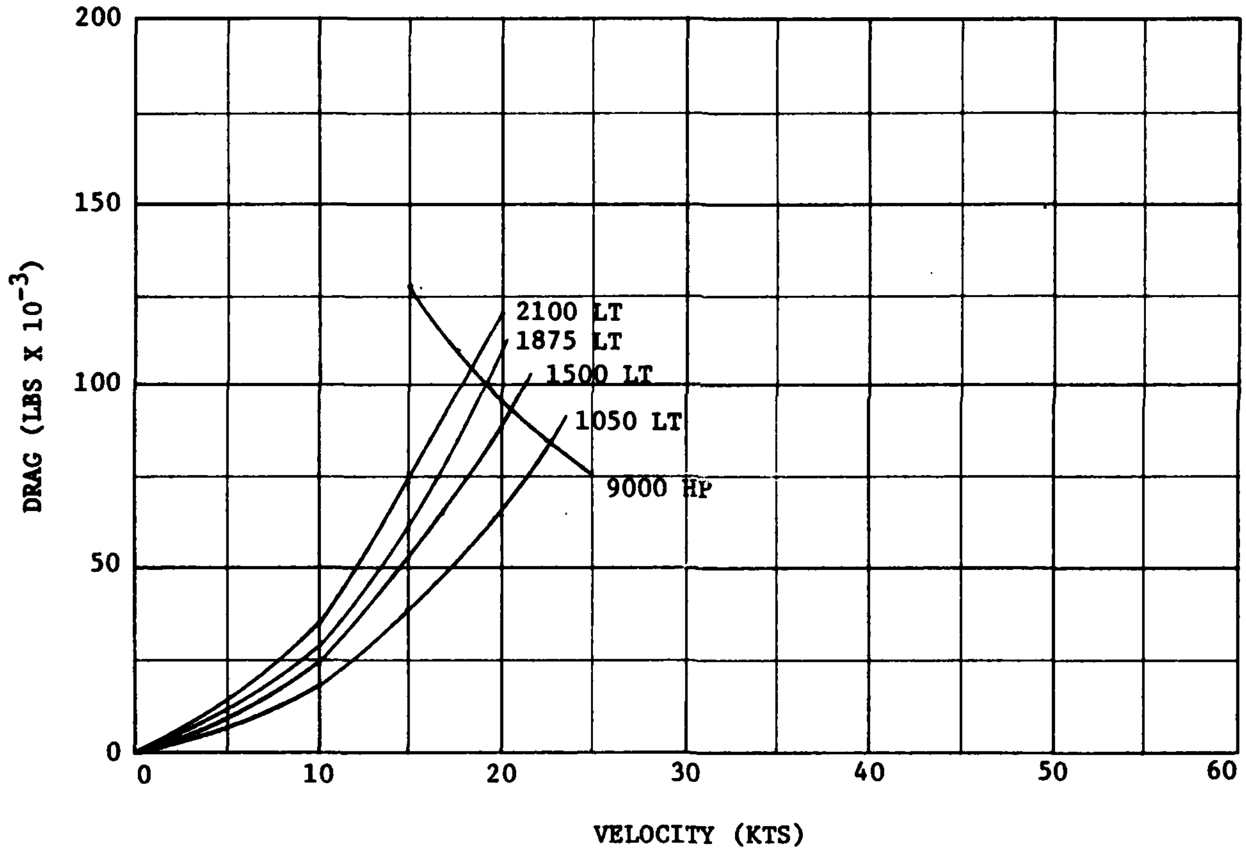


Figure 1.6-3. WHEC-SES Speed, Drag and Power Hullborne - Sea State 0

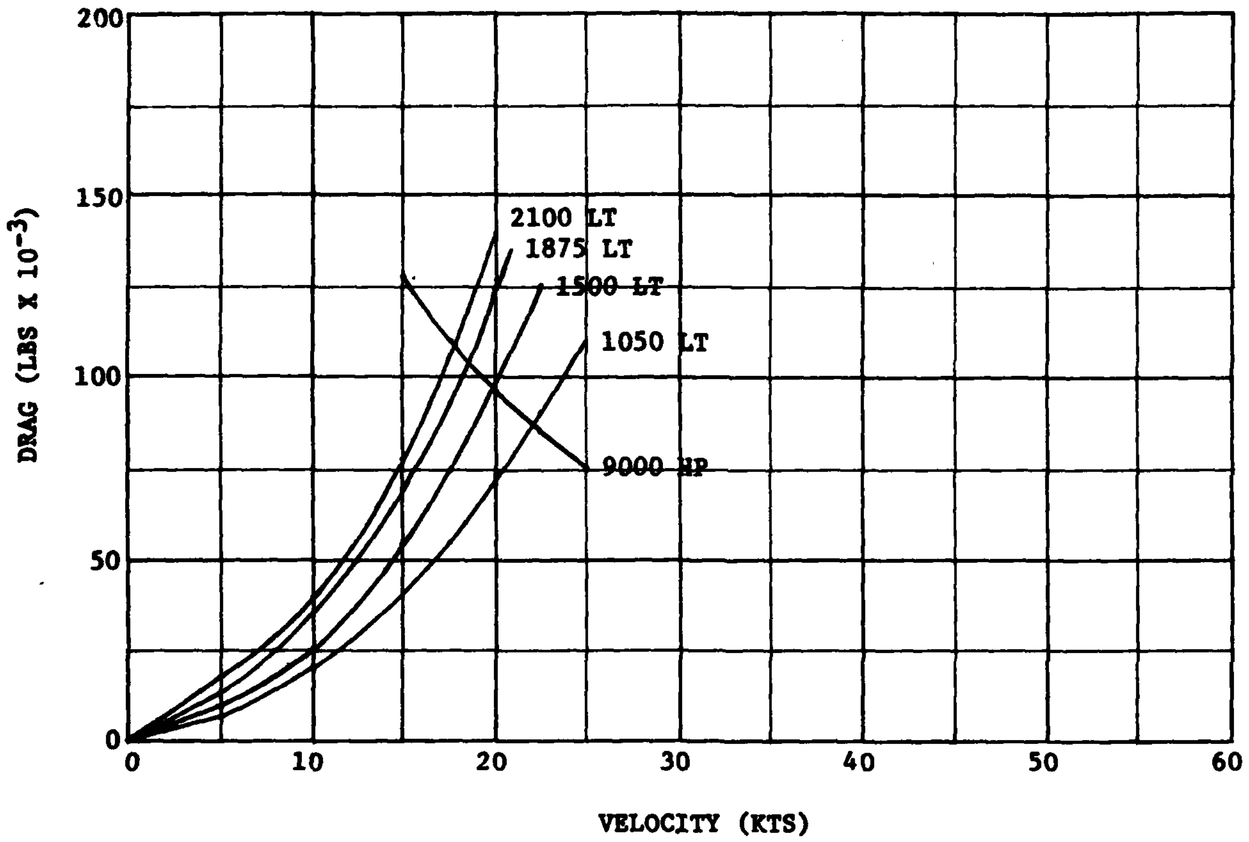


Figure 1.6-4. WHEC-SES Speed, Drag and Power Hullborne - Sea State 3

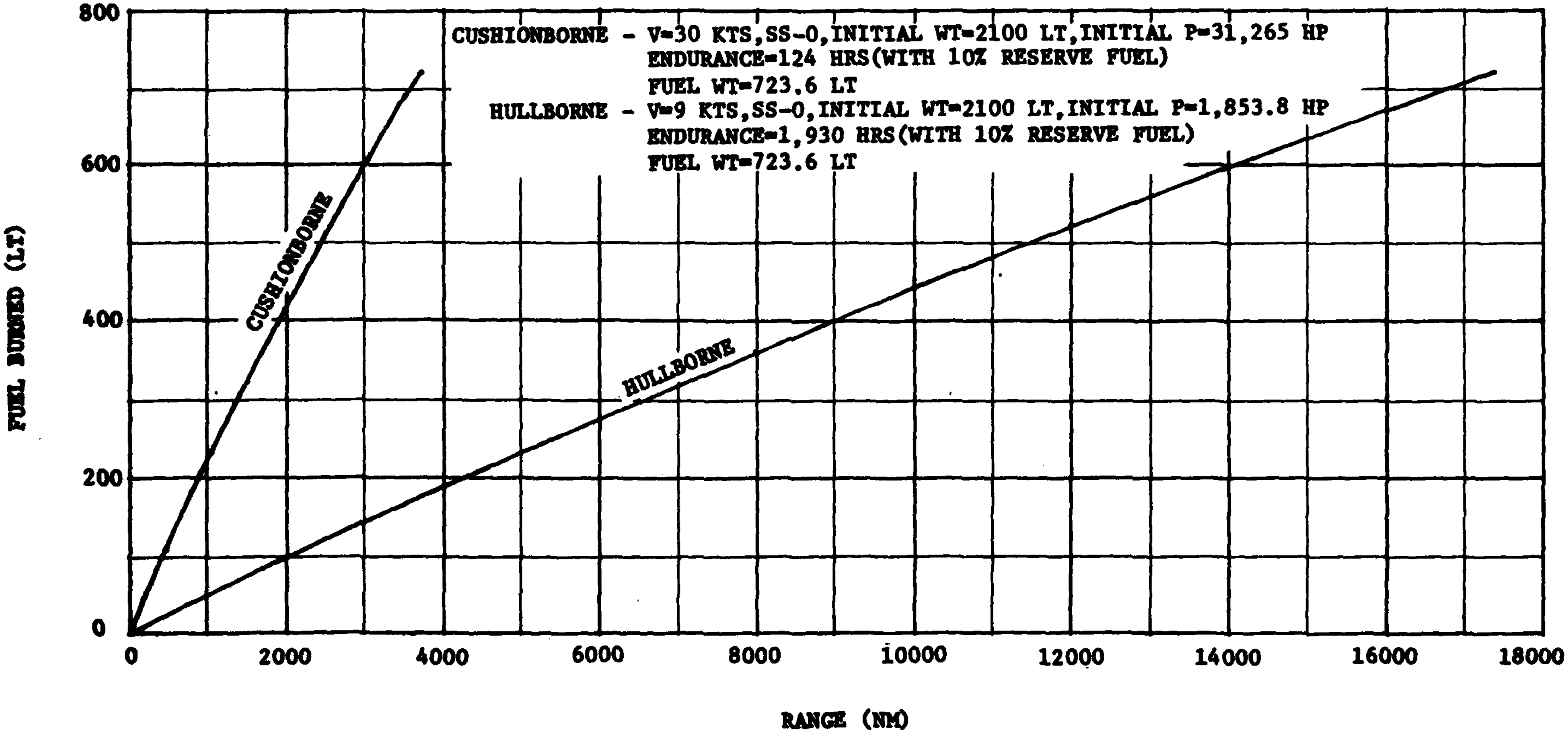


Figure 1.6-5. WHEC-SES Range Capability

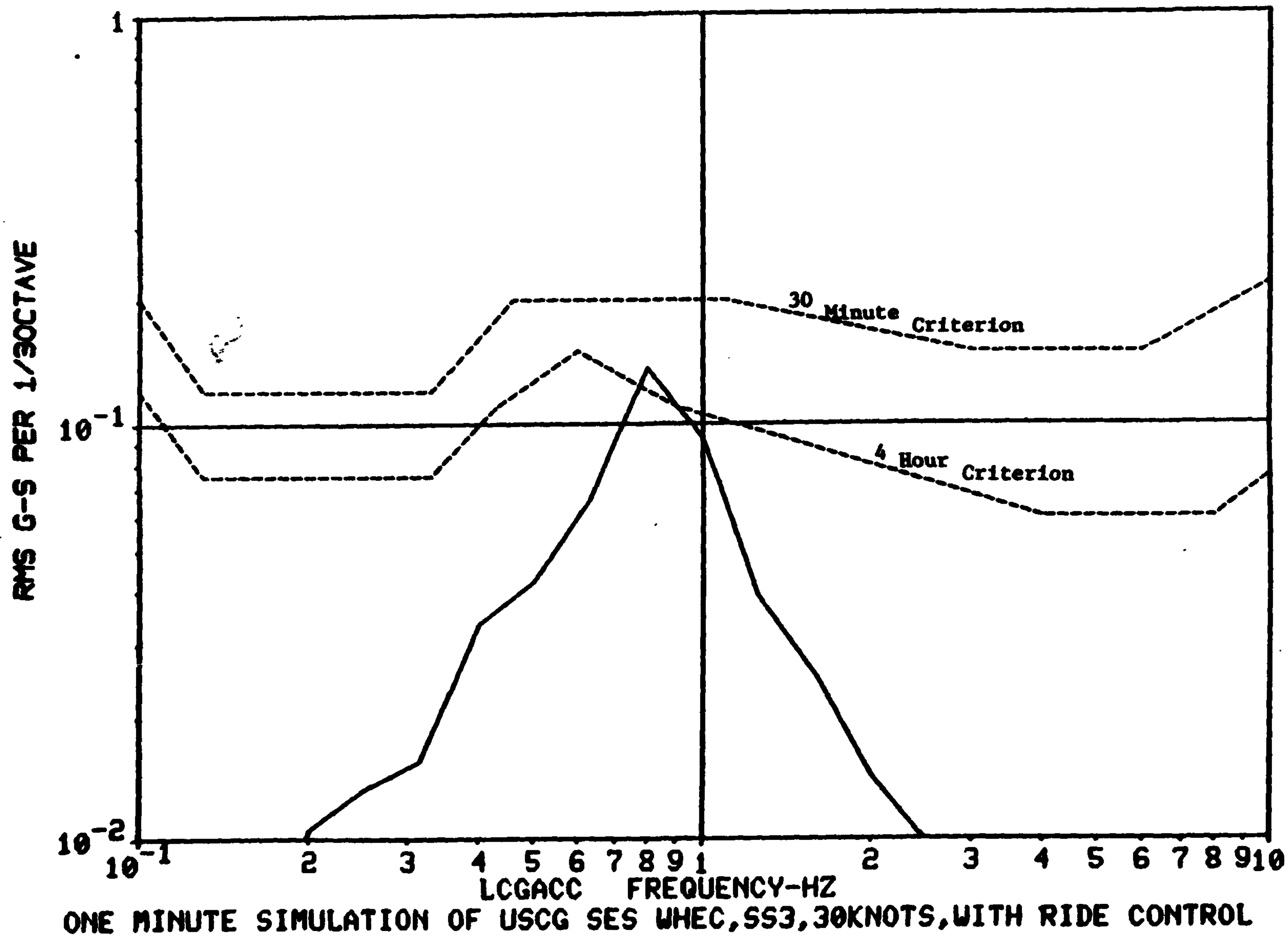


Figure 1.6-6. WHEC-SES Ride Quality - 30 Knots in Sea State 3 - Cushionborne with Ride Control

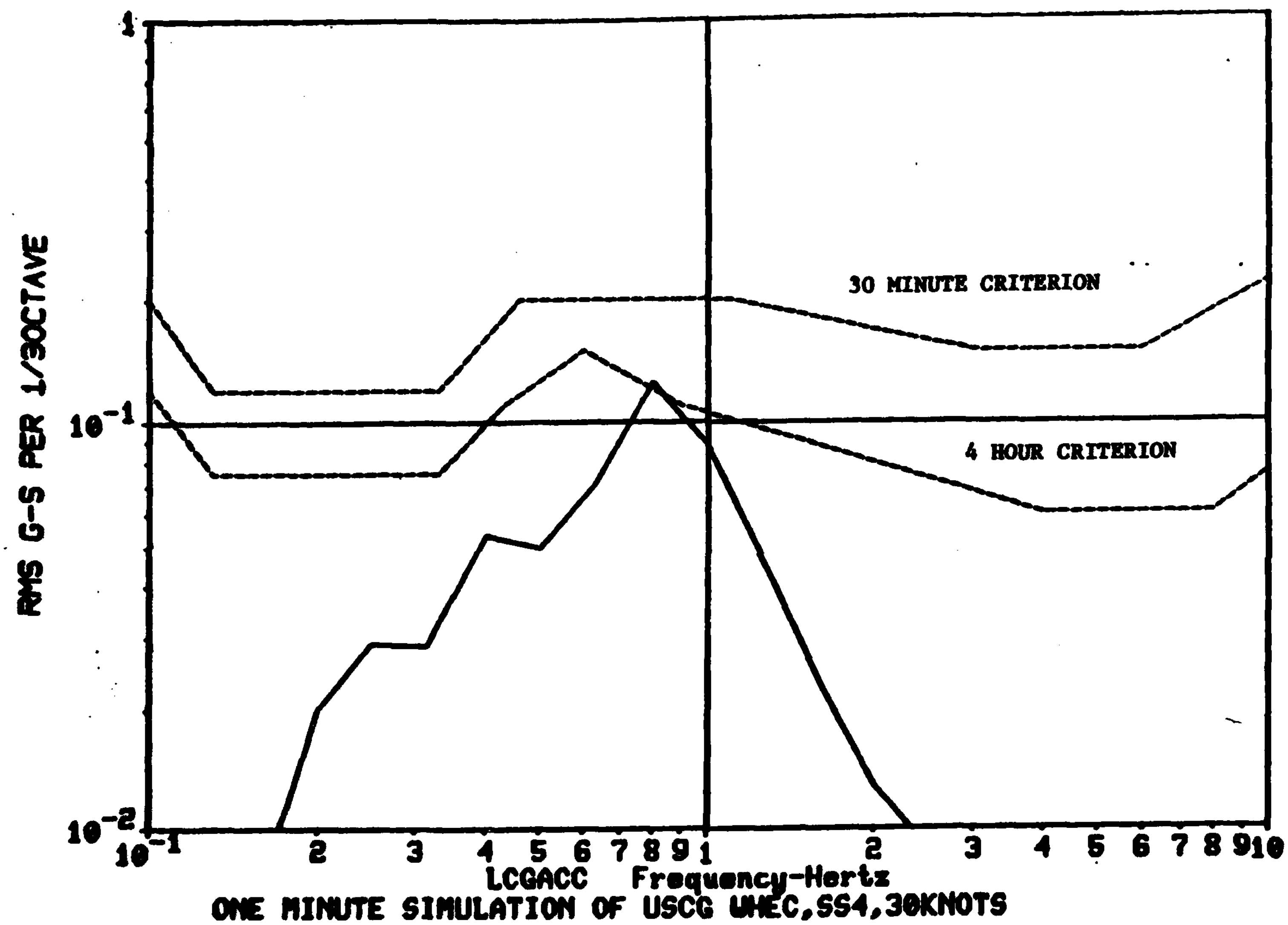


Figure 1.6-7. WHEC-SES Ride Quality - 30 Knots in Sea State 4 - Cushionborne with Ride Control

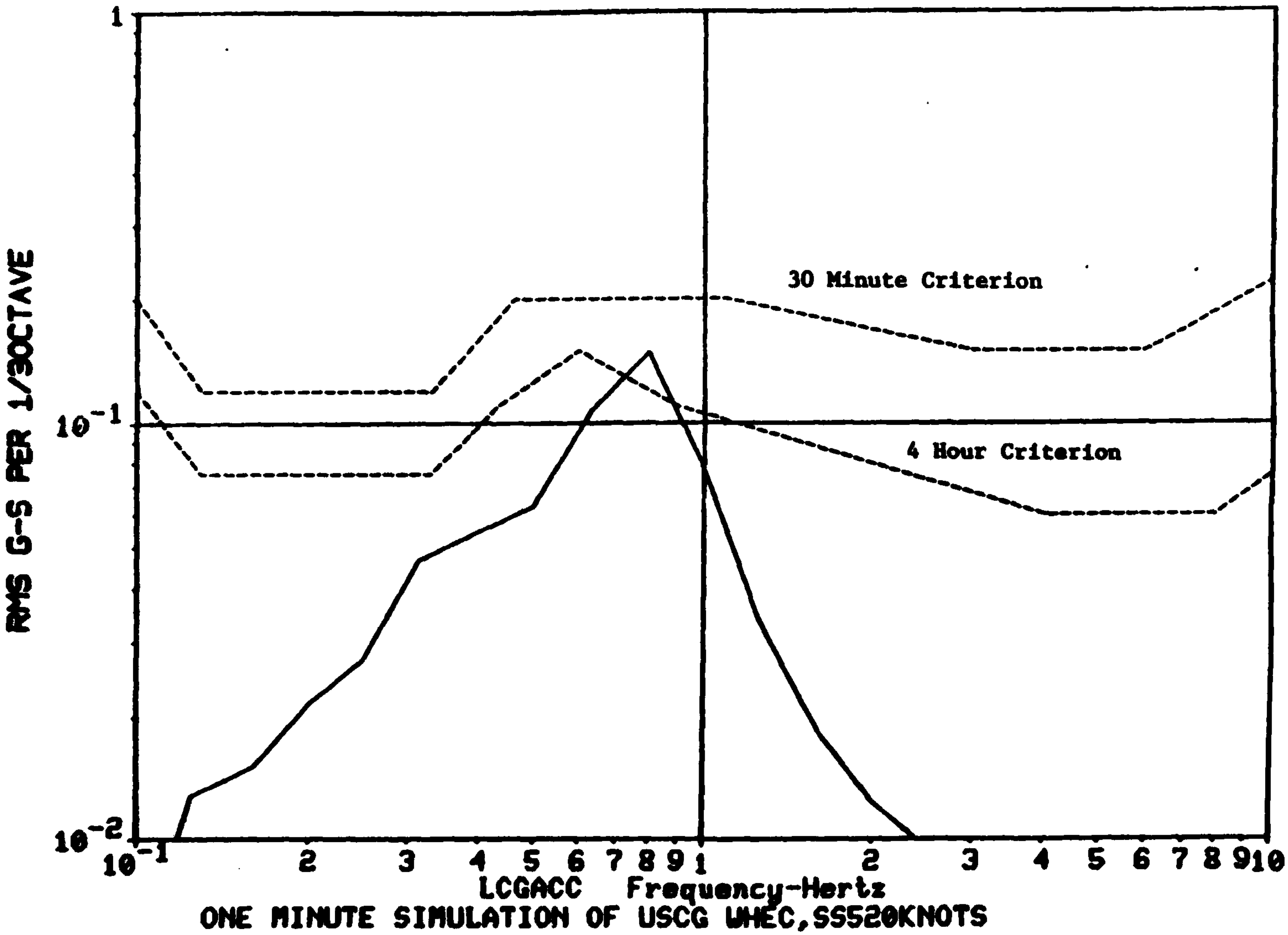


Figure 1.6-8. WHEC-SES Ride Quality - 20 Knots in Sea State 5 - Cushionborne with Ride Control

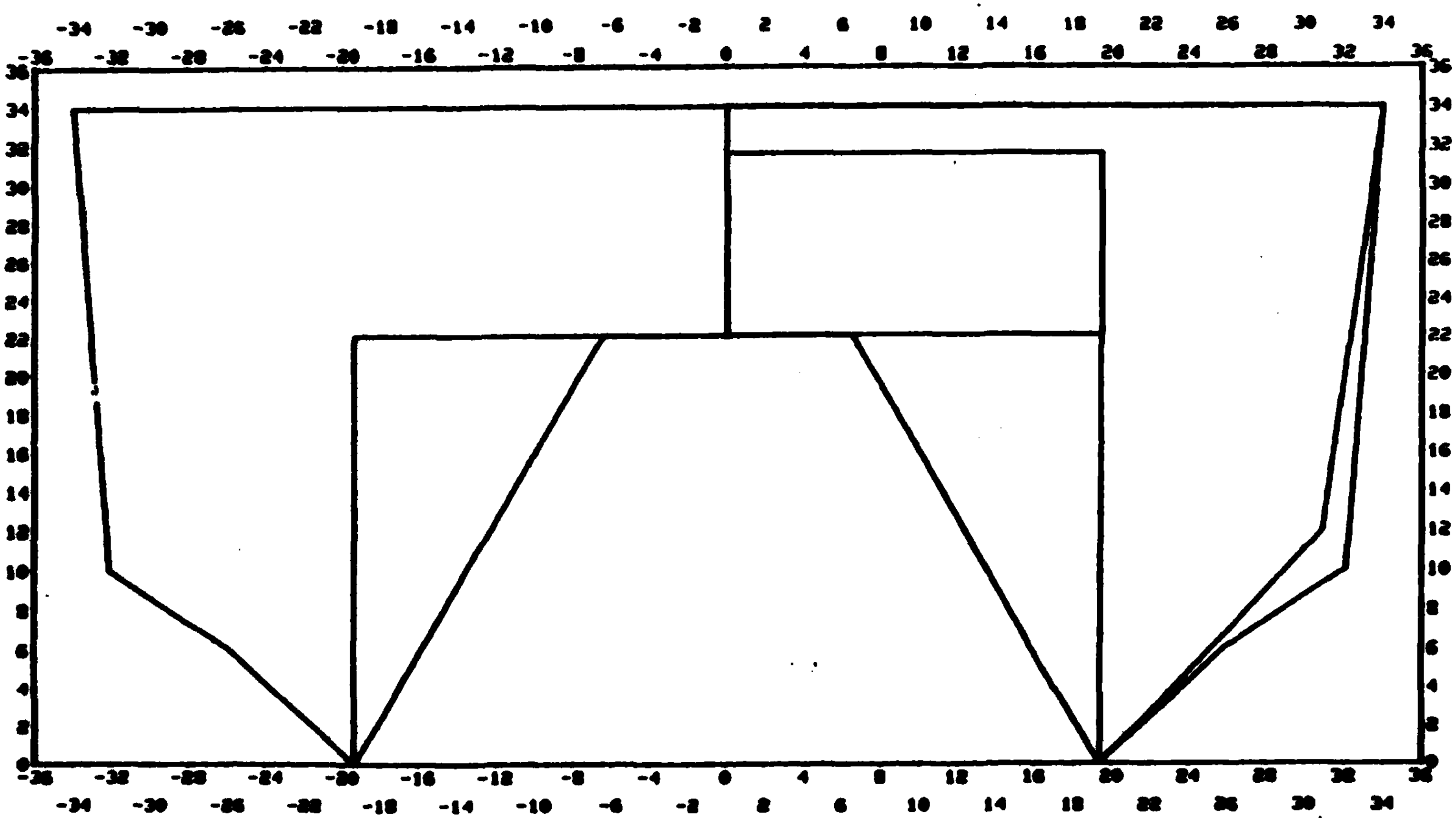


Figure 1.6-9. WHEC-SES Hydrostatic Analysis - Transverse Sections

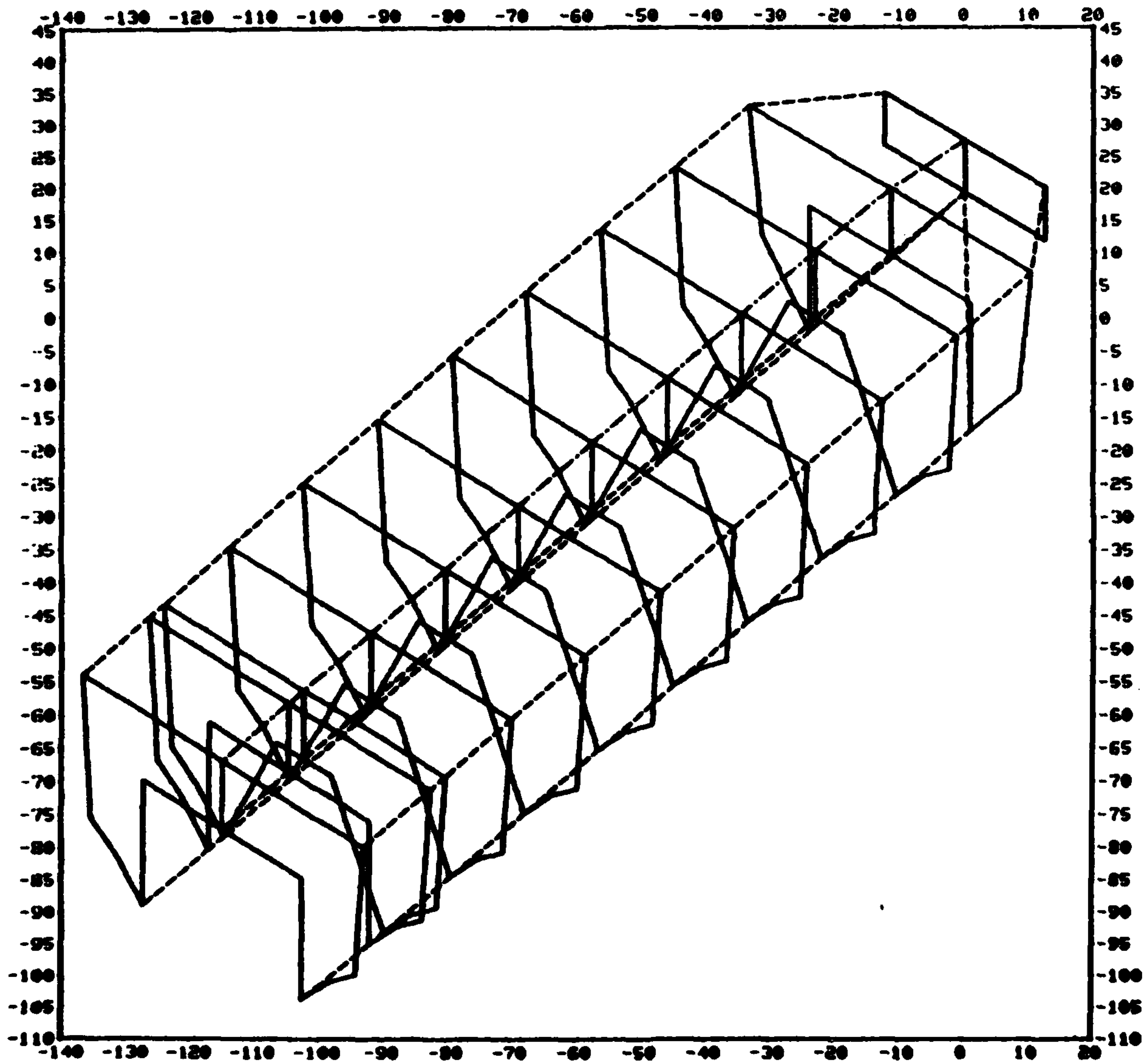


Figure 1.6-10. WHEC-SES Hydrostatic Analysis - Hull Geometry

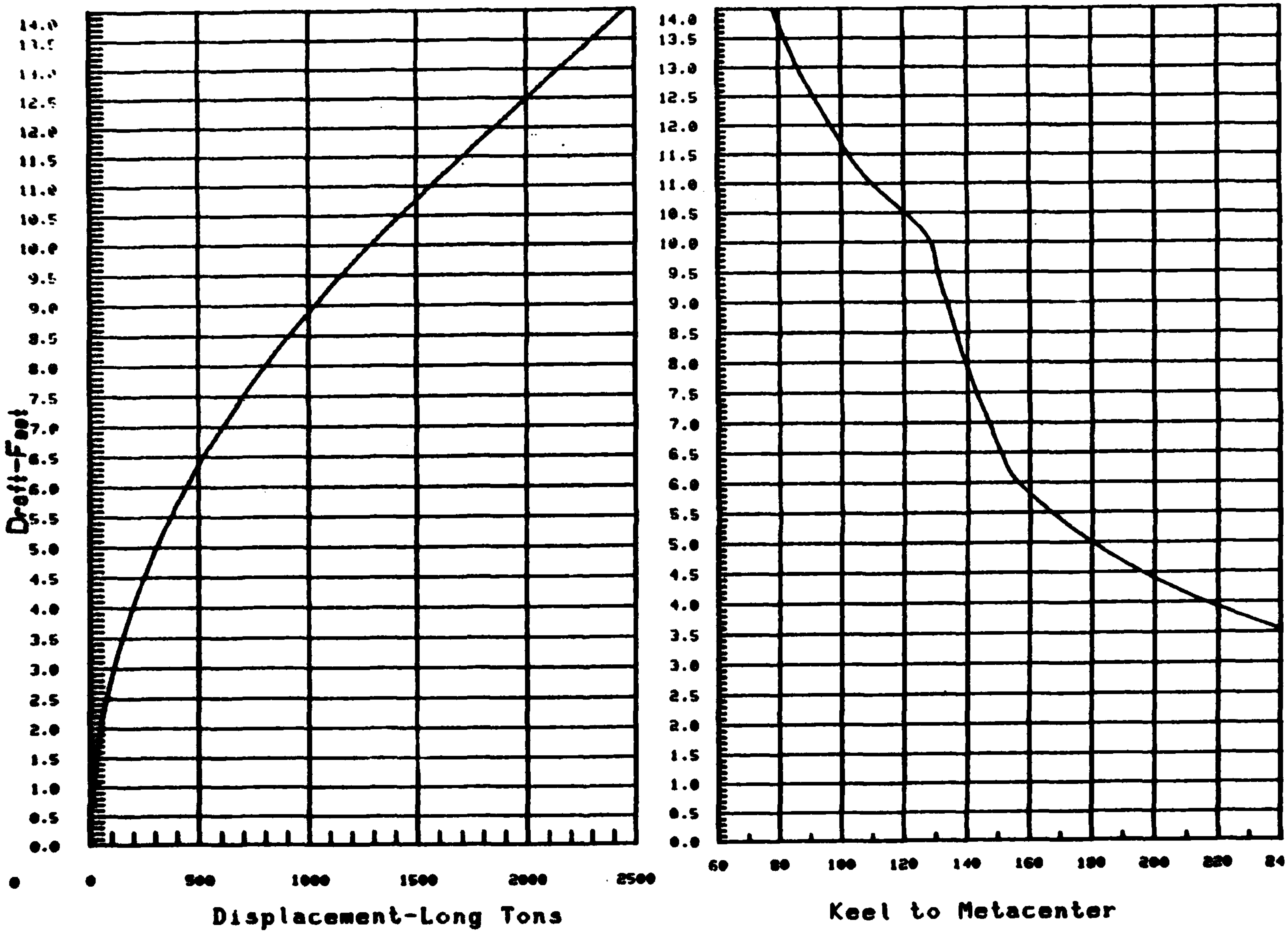


Figure 1.6-11. WHEC-SES Displacement, Draft, and Transverse Metacenter

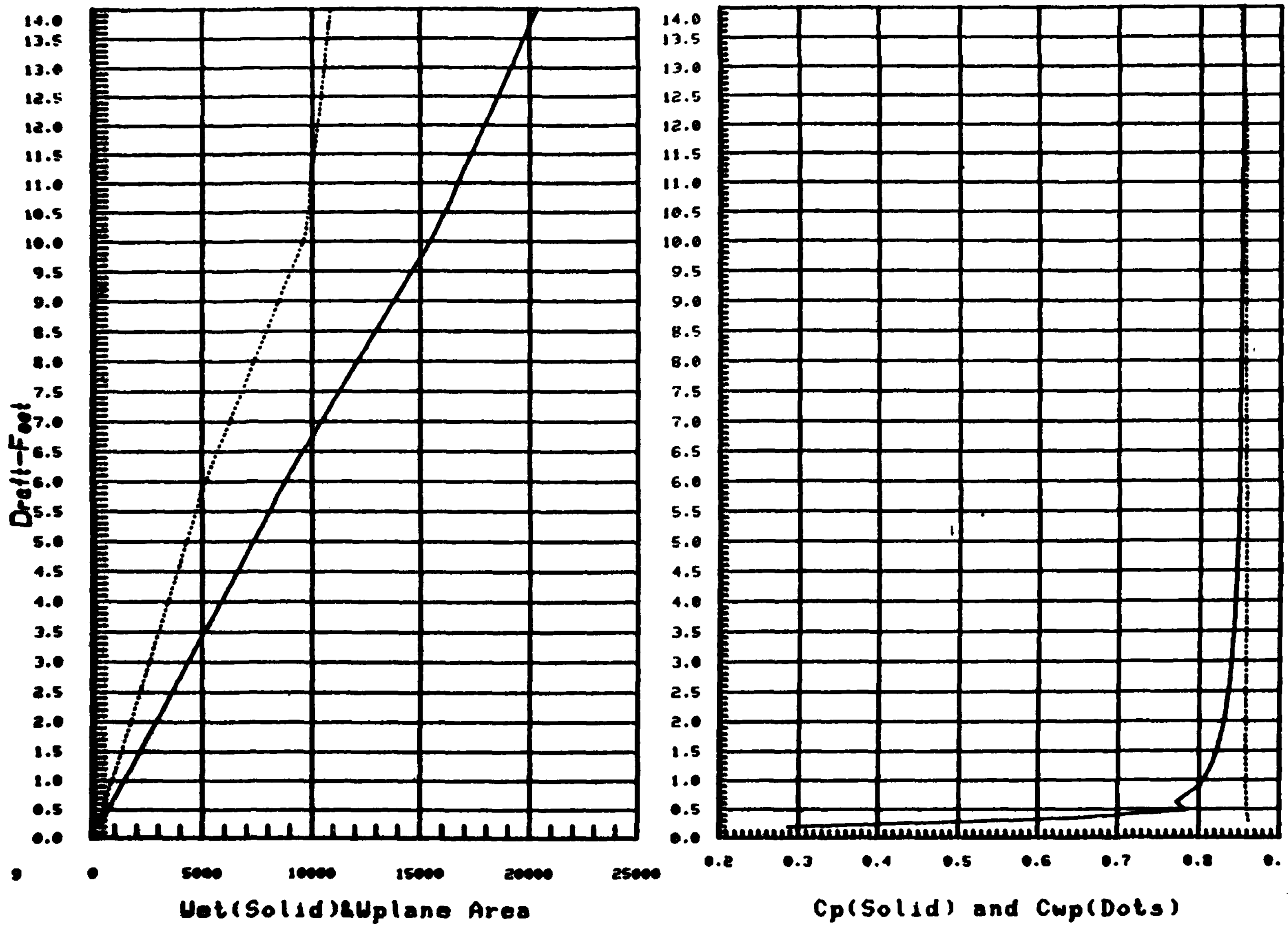


Figure 1.6-12. WHEC-SES Waterplane Area, Prismatic Coefficient and Waterplane Area Coefficient

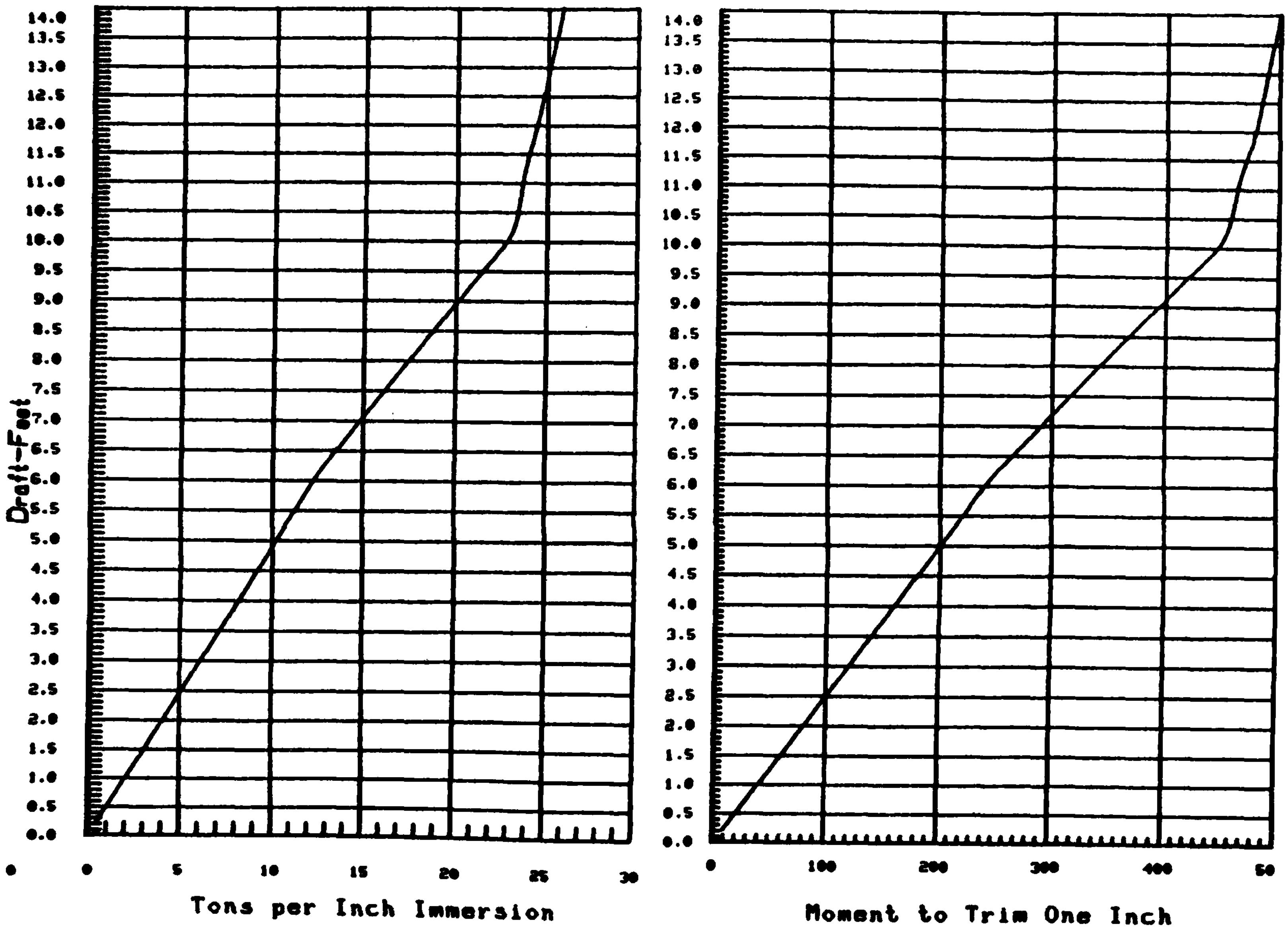


Figure 1.6-13. WHEC-SES Tons Per Inch Immersion and Moment to Change Trim One Inch

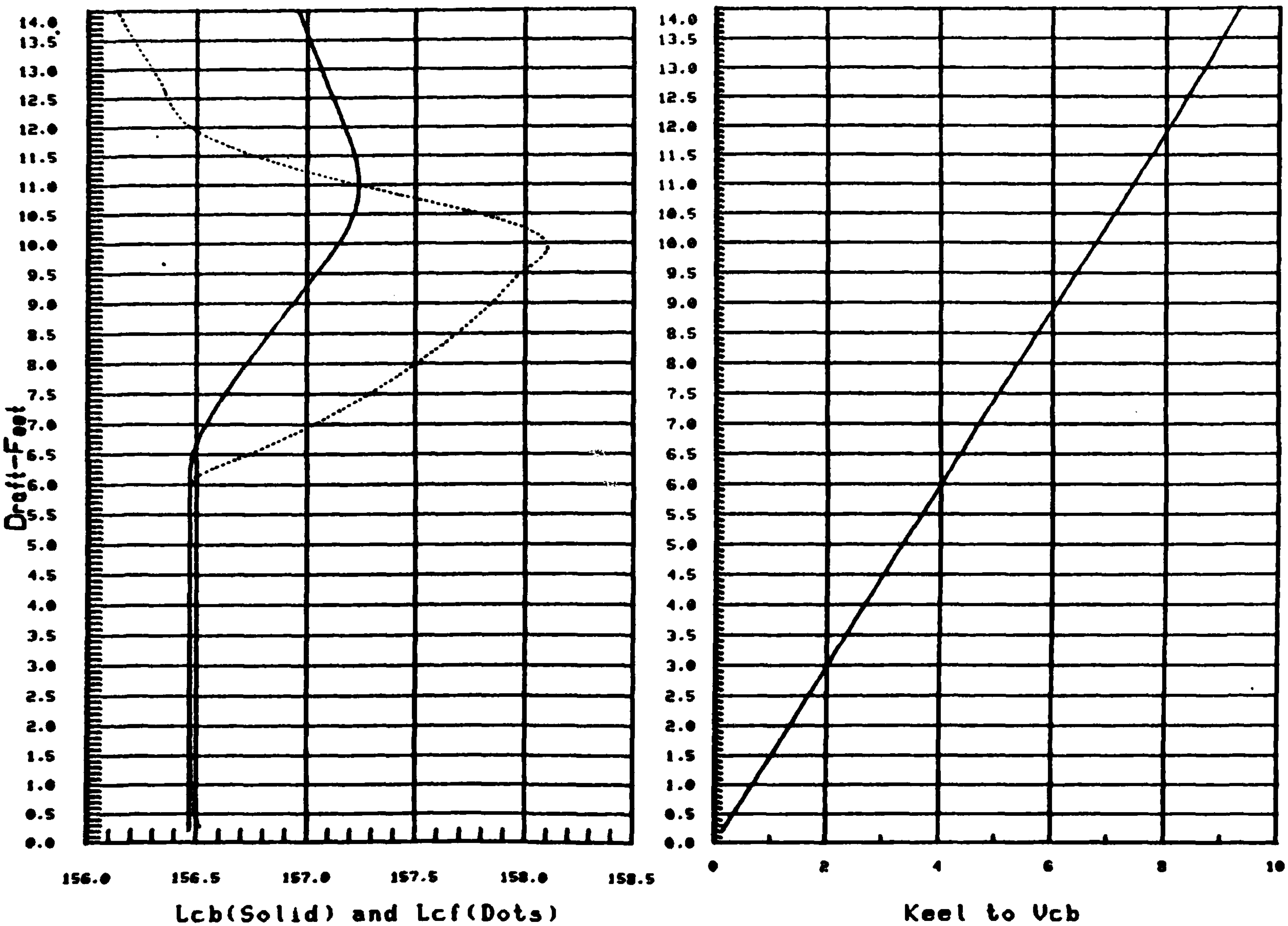


Figure 1.6-14. WHEC-SES LCB, LCF and VCB

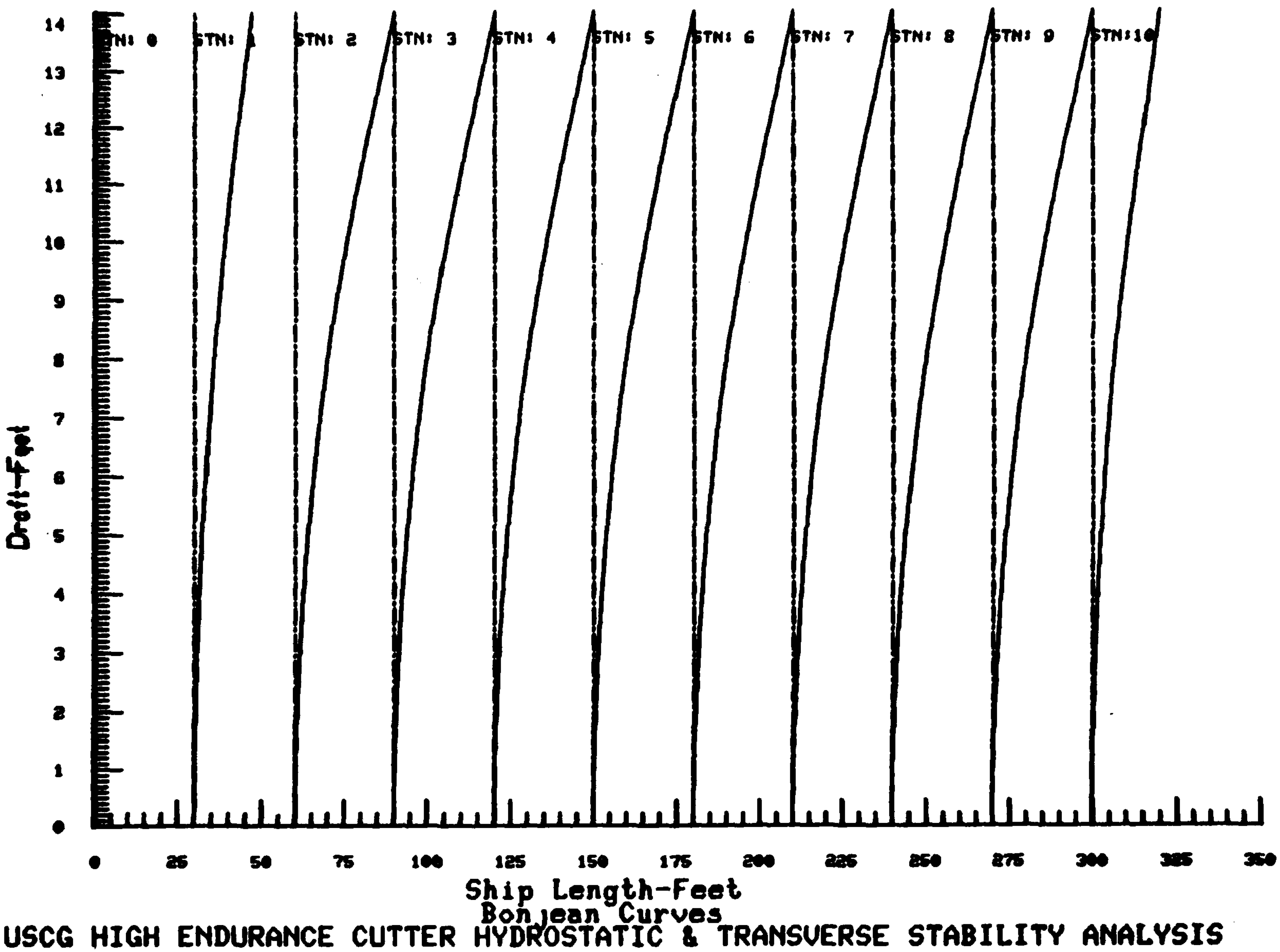
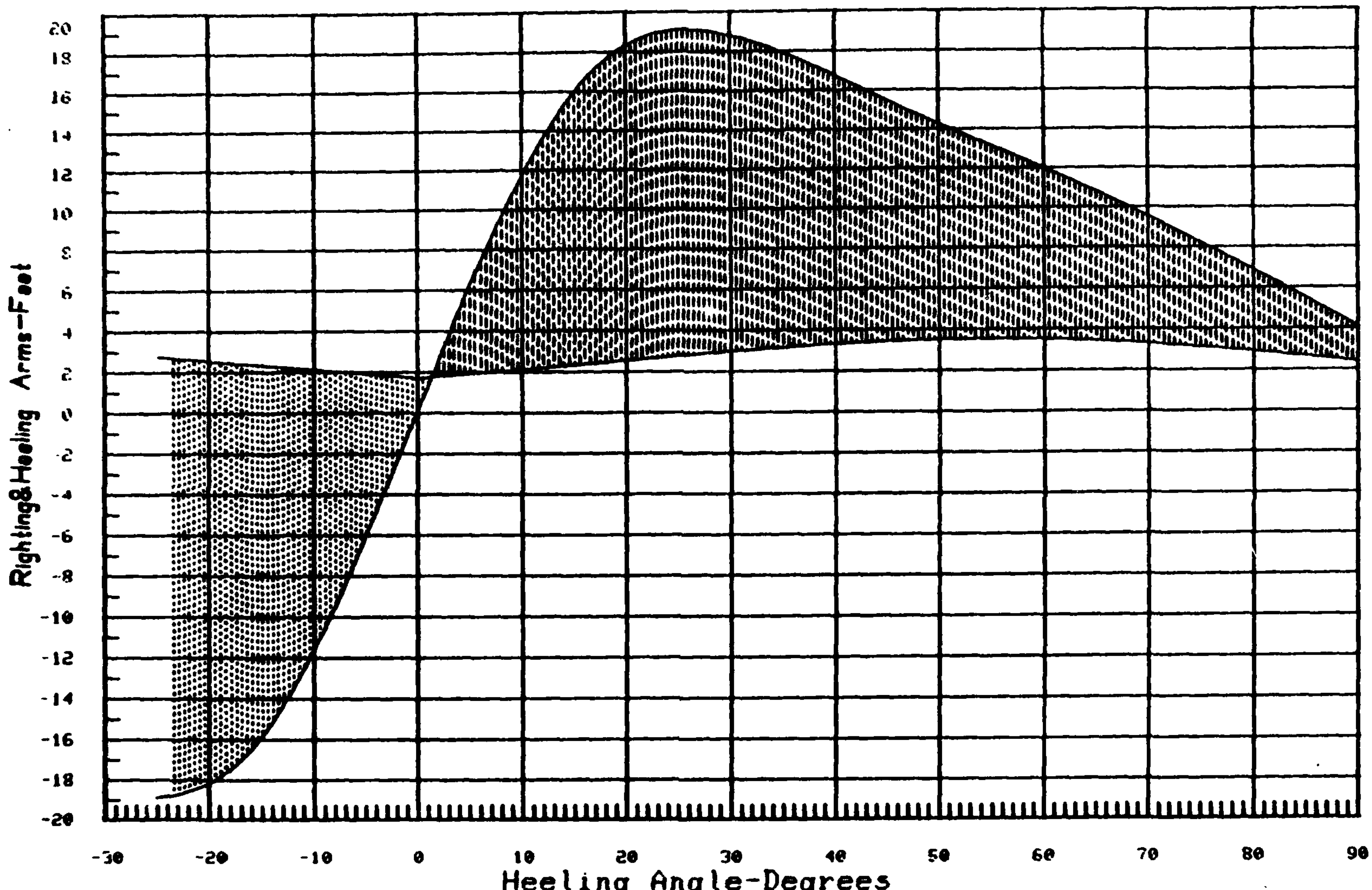


Figure 1.6-15. WHEC-SES Bonjean Curves



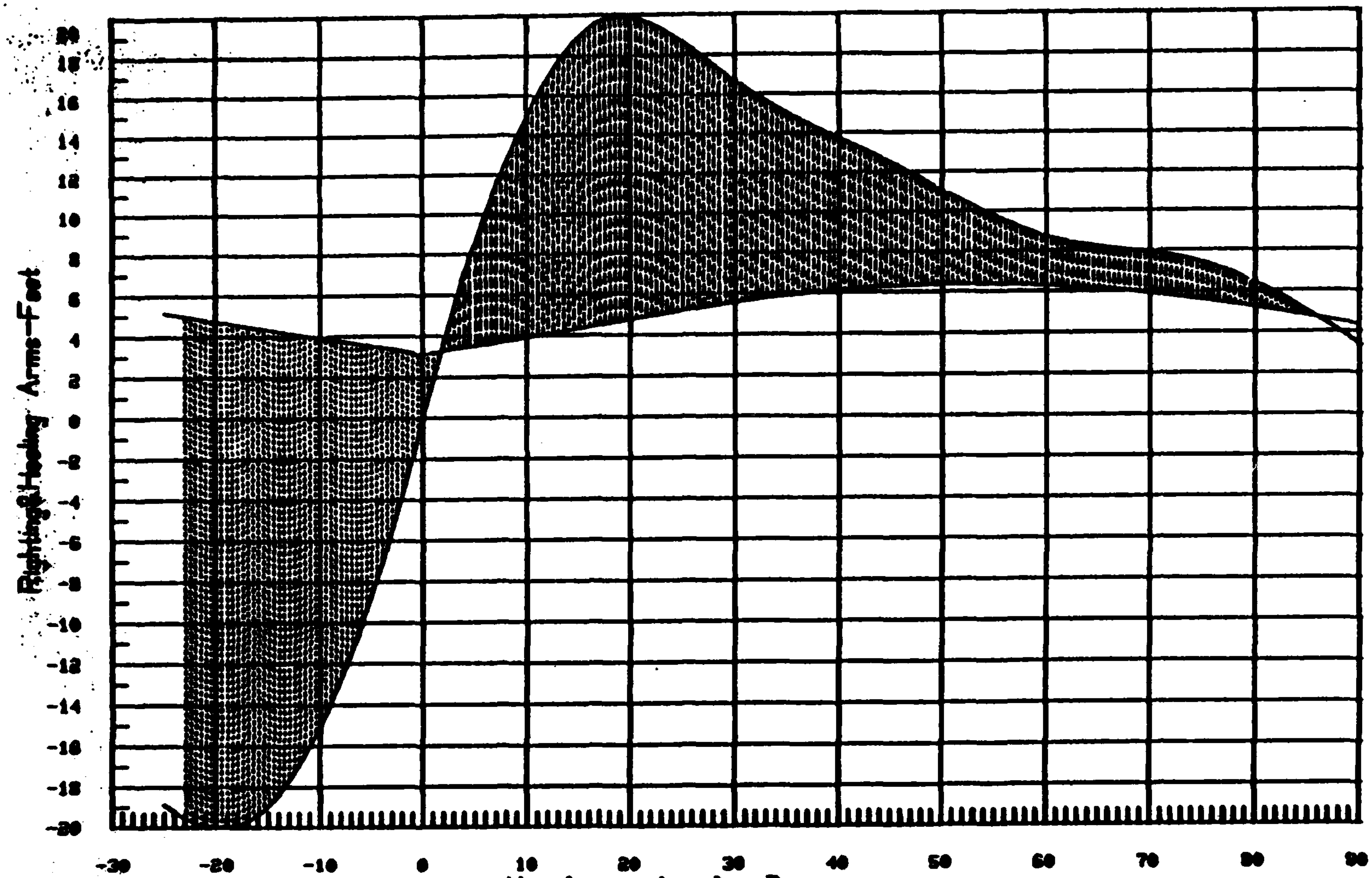
U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.40

Hydrostatic Properties for Ship in Intact Condition Rolling Angle=25 Degrees A1/A2= 2.55

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
2100.0	300.0	68.0	12.8	33.2	0.0	17.0	156.9	487.1	25.0	0.85	0.85	70.5	100.

Transverse Stabilitu-Beam Wind Combined with Rolling

Figure 1.6-16. WHEC-SES Intact Stability Wind Heel Full Load Condition

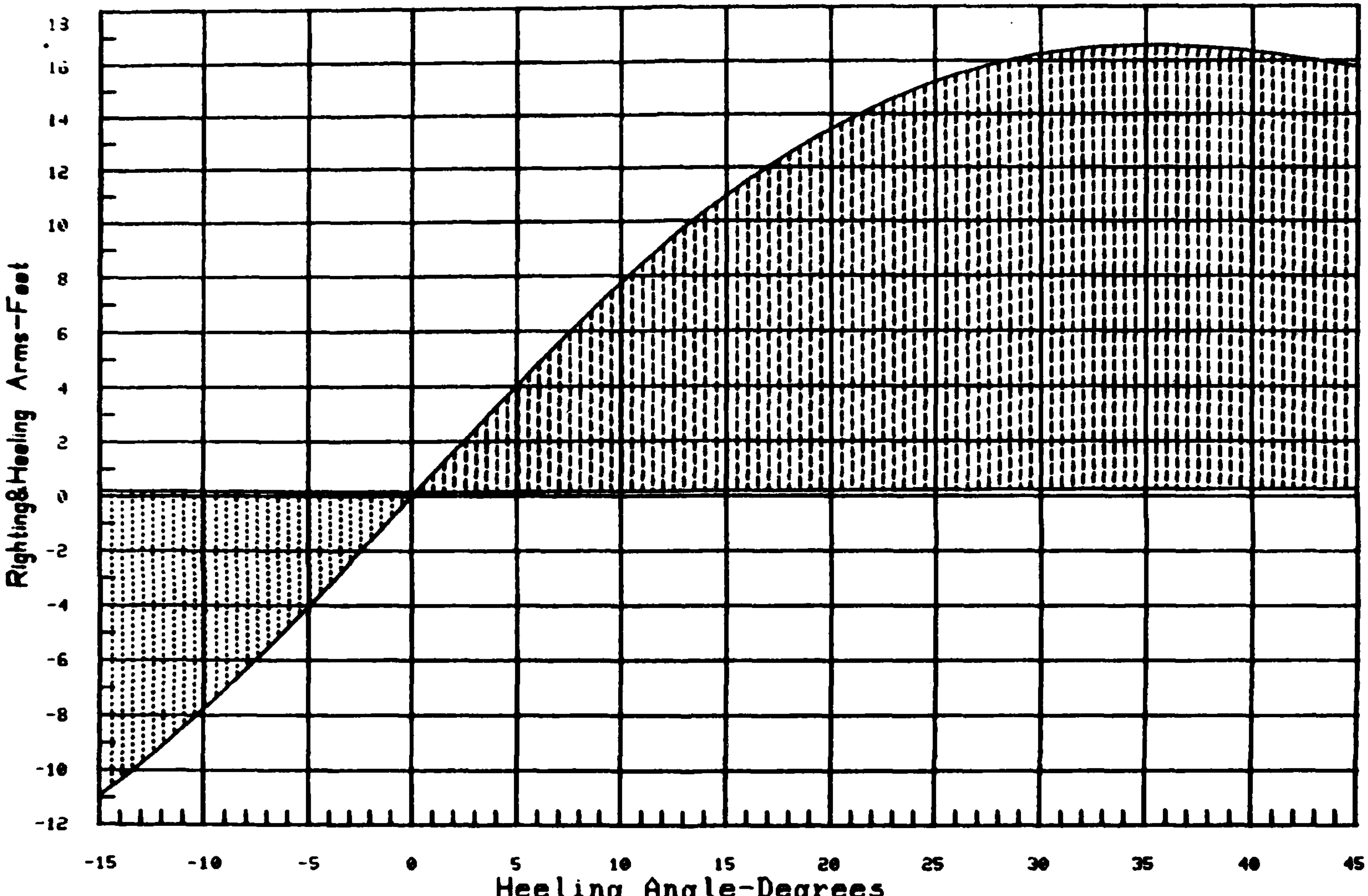


U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.40
Hydrostatic Properties for Ship in Intact Condition Rolling Angle=25 Degrees A1/A2= 1.30

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
1230.0	300.0	68.0	9.9	33.2	-0.1	18.7	156.8	442.5	22.4	0.87	0.87	100.6	100.

Transverse Stability-Beam Wind Combined with Rolling
USCG HIGH ENDURANCE CUTTER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 1.6-17. WHEC-SES Intact Stability Wind Heel Burned Out Condition

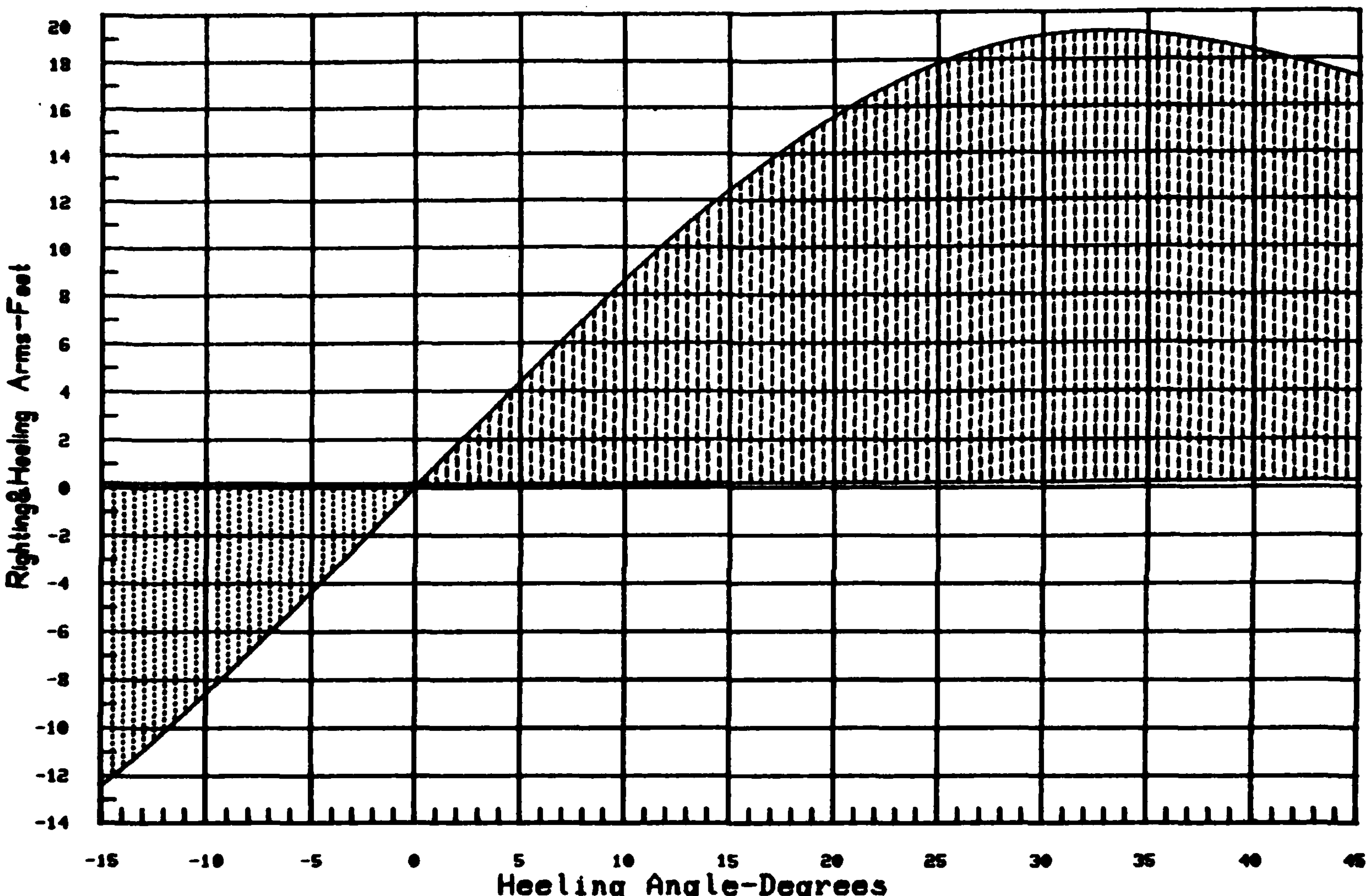


U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 0 and 99 Permeability(Port)=0.95 Permeability(Starboard)=0.95 Rolling Angle=15 Degrees A1/A2= 6.37

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
2100.0	300.0	68.0	34.7	33.2	-5.9	17.8	156.9	502.7	25.4	0.87	0.87	71.0	30.

Transverse Stability-Beam Wind Combined with Rolling
USCG HIGH ENDURANCE CUTTER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 1.6-18. WHEC-SES Damage Stability Compartments 1 and 2, Shell-to-Shell Damage

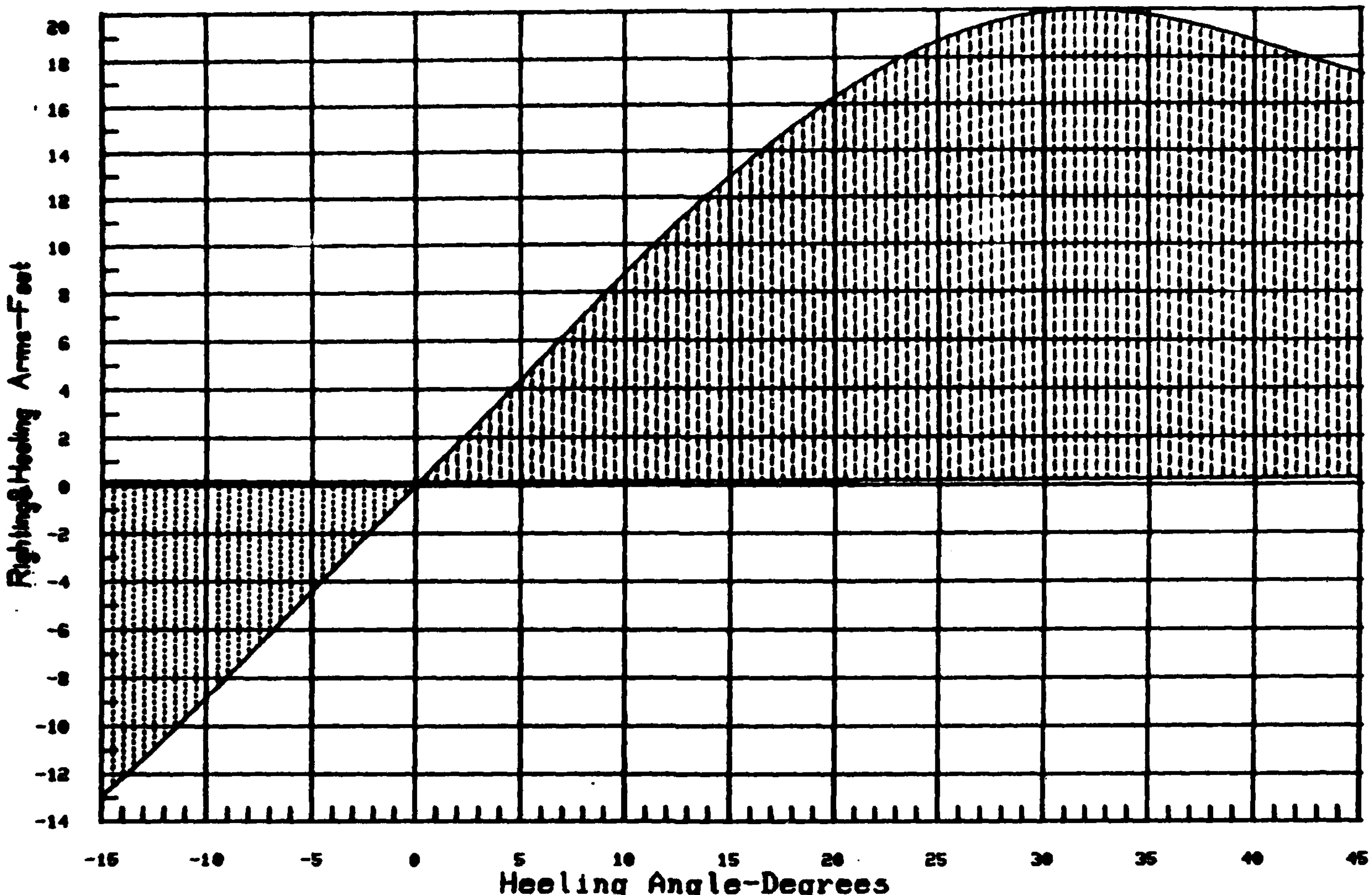


U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 48 and 156 Permeability(Port)=0.95 Permeability(Starboard)=0.95 Rolling Angle=15 Degrees A1/A2= 6.61

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
2100.0	300.0	68.0	23.8	33.2	-2.3	17.8	156.9	502.7	25.4	0.87	0.87	71.0	30.

Transverse Stability-Beam Wind Combined with Rolling
USCG HIGH ENDURANCE CUTTER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 1.6-19. WHEC-SES Damage Stability Compartments 2 and 3, Shell-to-Shell Damage



U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 99 and 210 Permeability(Port)-0.95 Permeability(Starboard)-0.95 Rolling Angle-15 Degrees A1/A2- 6.67

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
2100.0	300.0	68.0	14.5	30.4	0.5	17.8	156.9	502.7	25.4	0.87	0.87	71.0	30.

Transverse Stability-Beam Wind Combined with Rolling
USCG HIGH ENDURANCE CUTTER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 1.6-20. WHEC-SES Damage Stability Compartments 3 and 4, Shell-to-Shell Damage

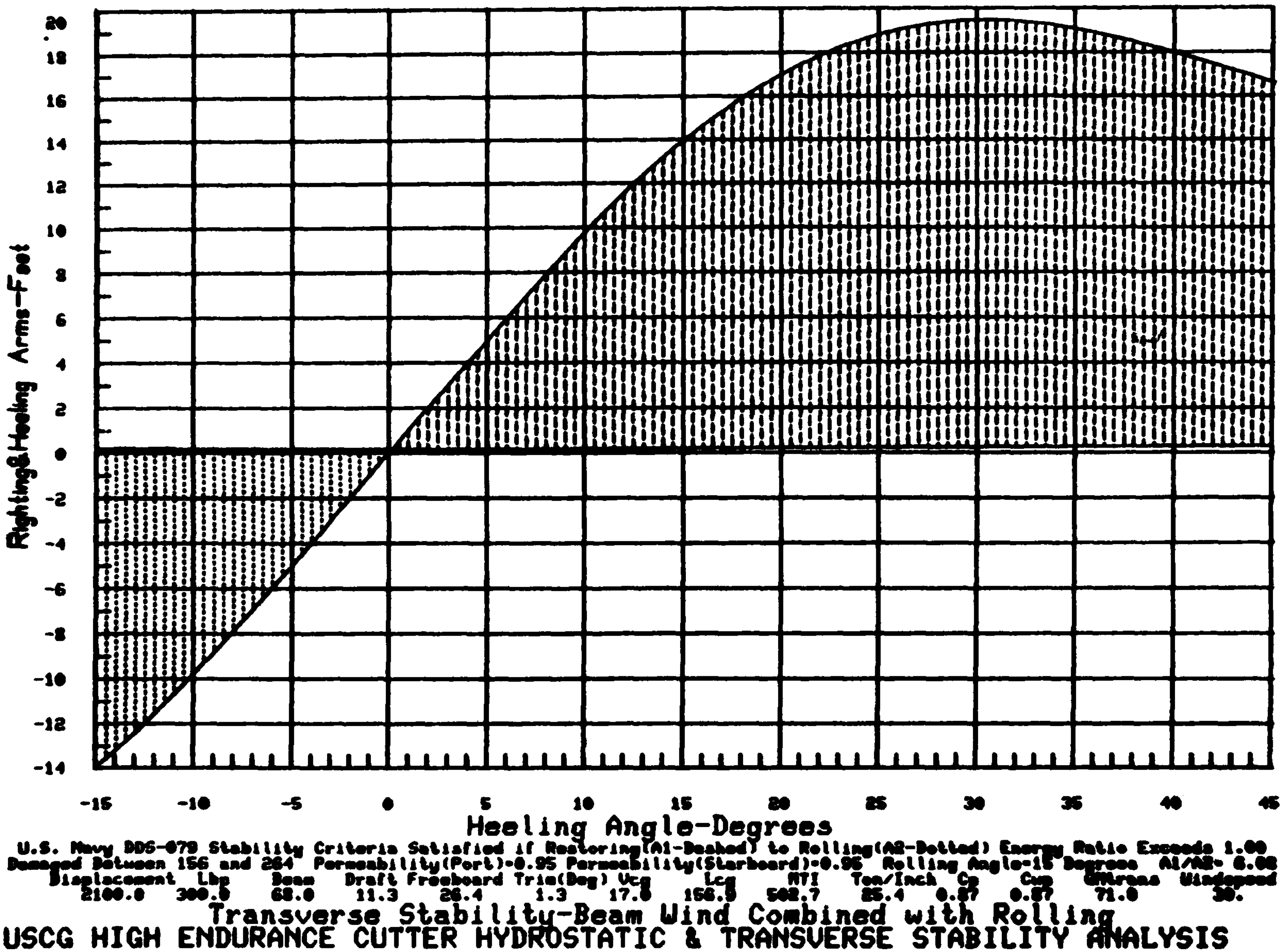


Figure 1.6-21. WHEC-SES Damage Stability Compartments 4 and 5 - Shell-to-Shell Damage

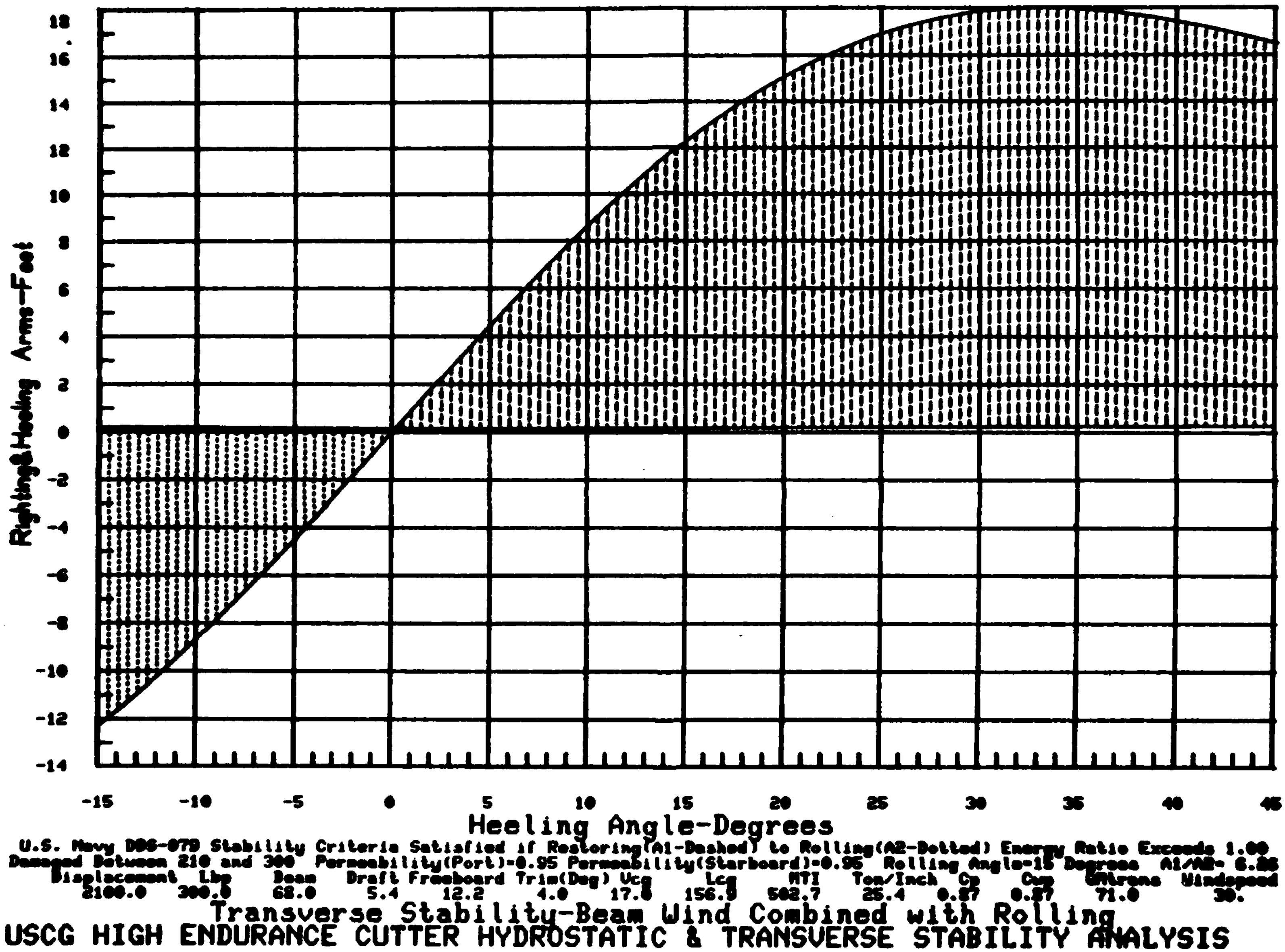
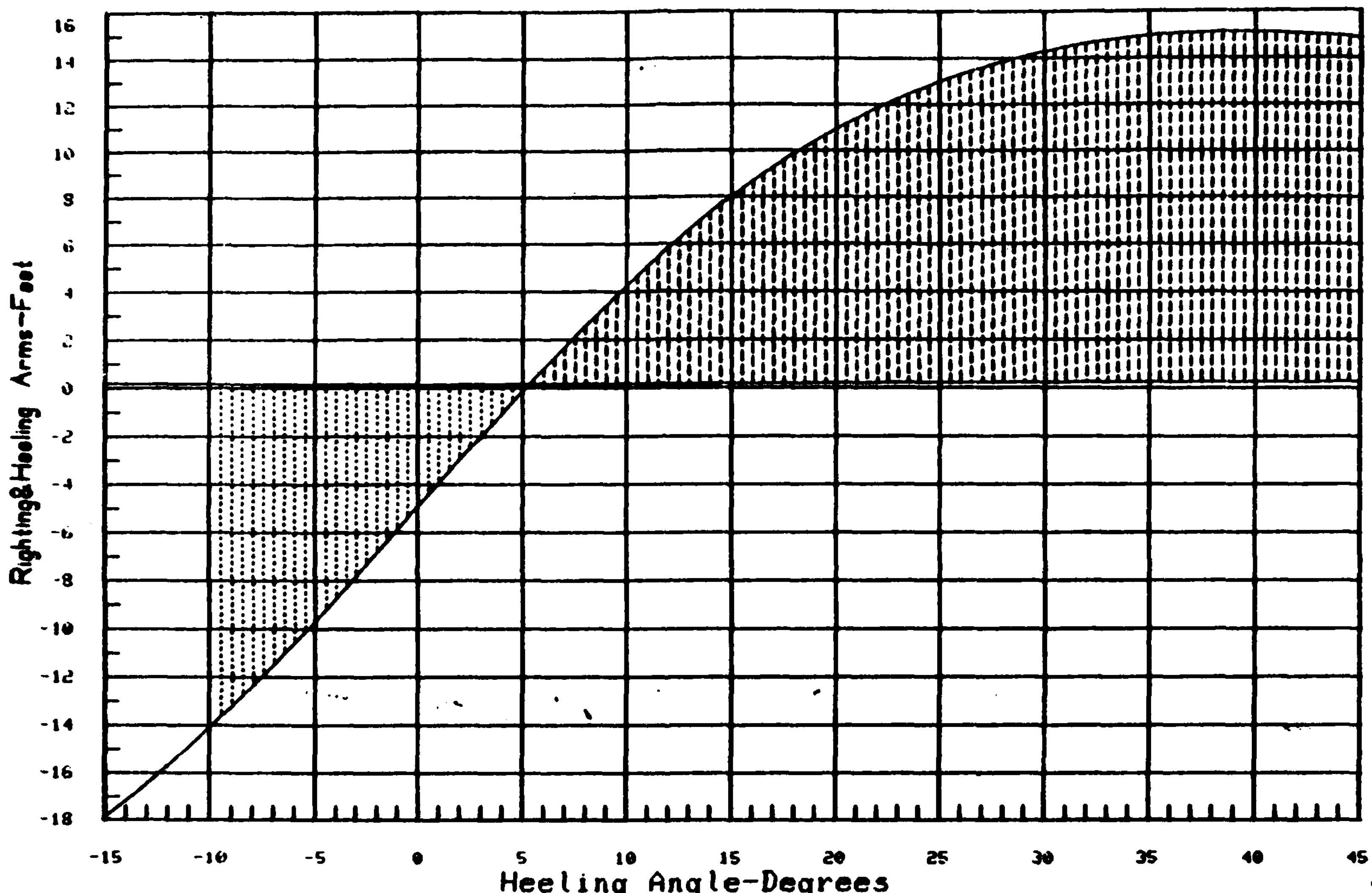


Figure 1.6-22. WHEC-SES Damage Stability Compartments 5 and 6, Shell-to-Shell Damage



U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged between 0.0 and 99.0 with Permeability-0.00 Port and 0.95 Starboard Rolling Angle-15 Degrees A1/A2- 4.12

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
2100.0	300.0	68.0	18.1	33.2	-1.4	17.0	156.9	487.1	25.0	0.85	0.85	70.5	30.

Transverse Stabilitu-Beam Wind Combined with Rolling

Figure 1.6-23. WHEC-SES Damage Stability Compartments 1 and 2, Damage to Centerline

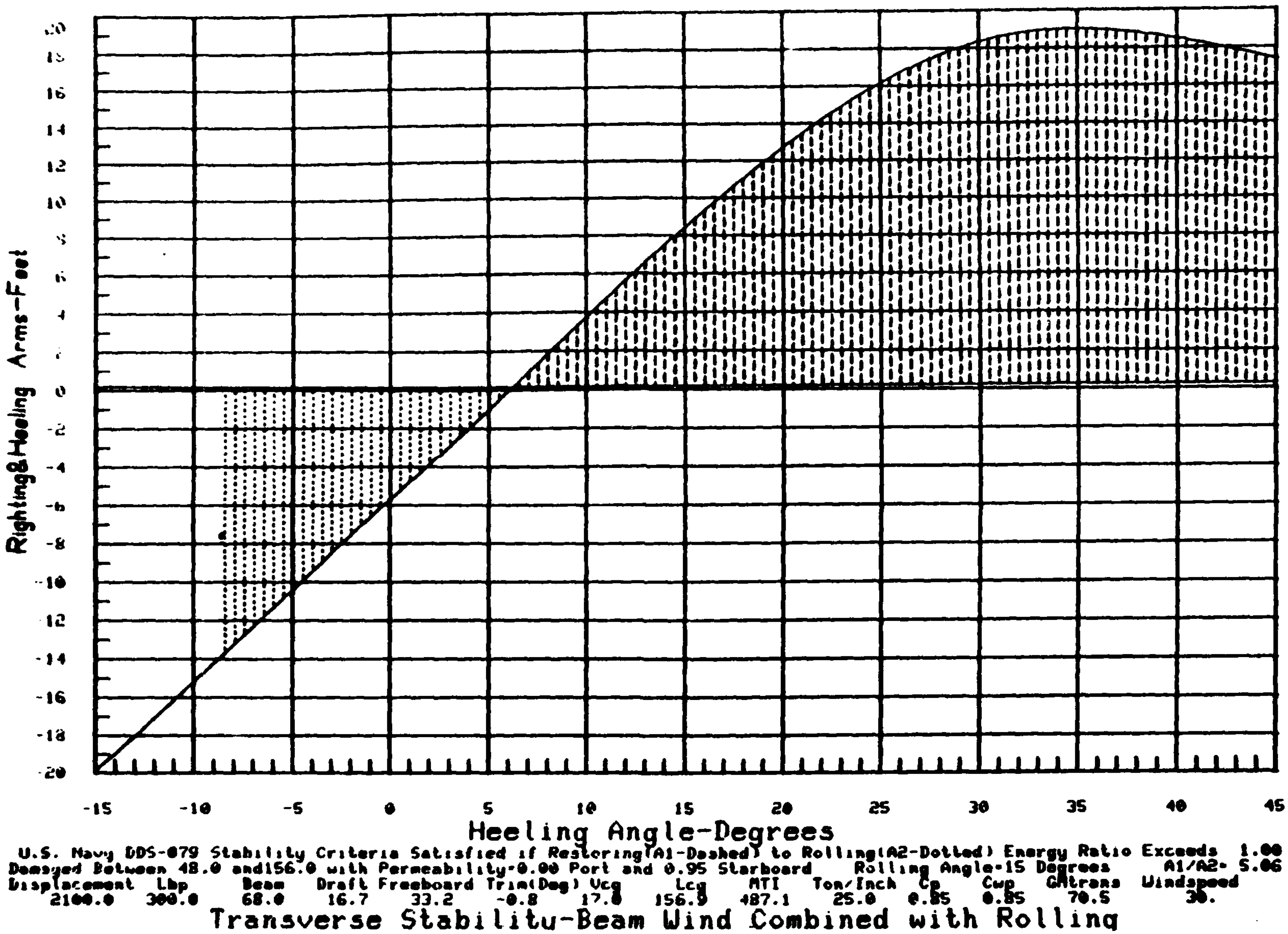


Figure 1.6-24. WHEC-SES Damage Stability Compartments 2 and 3, Damage to Centerline

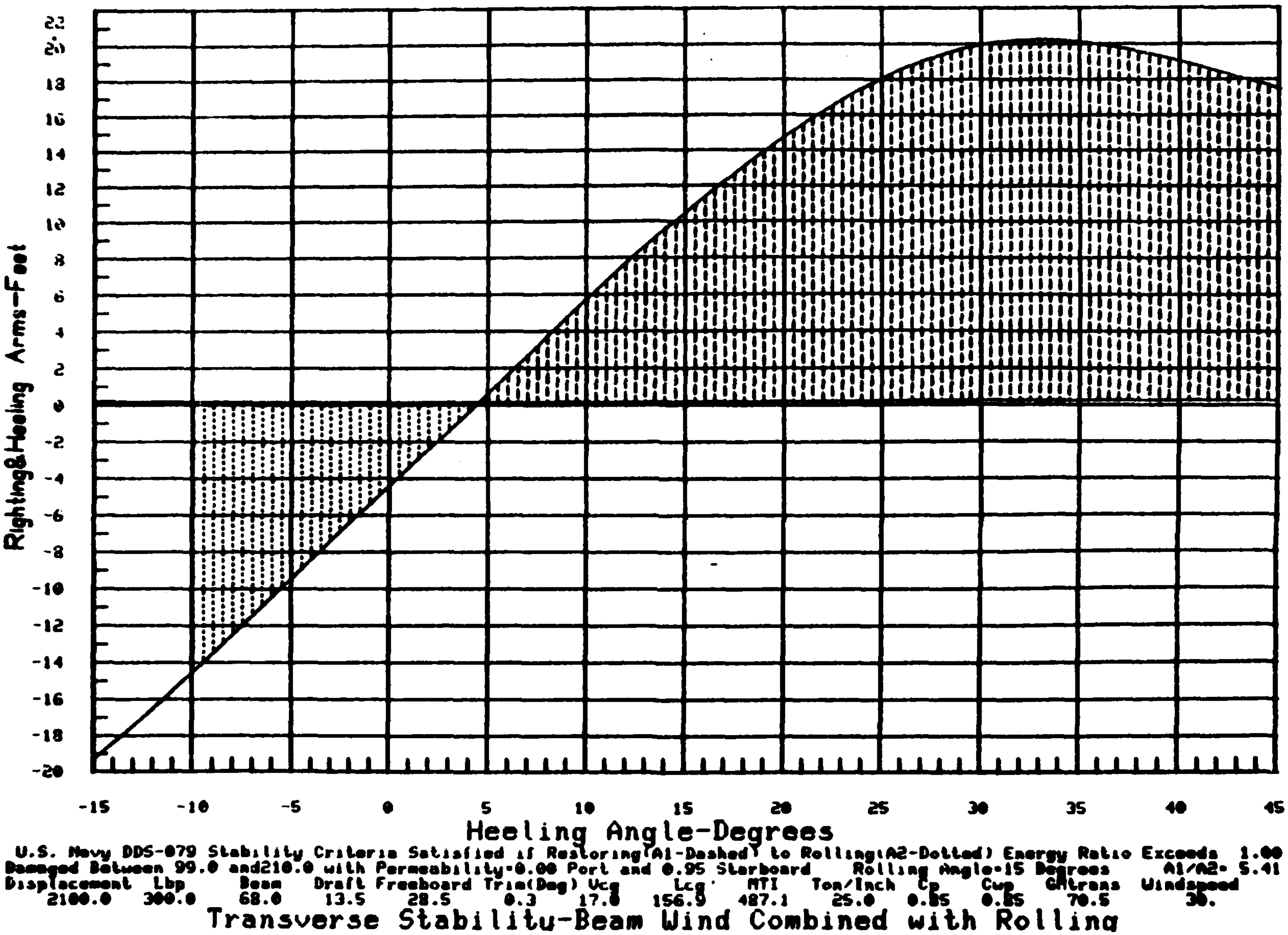


Figure 1.6-25. WHEC-SES Damage Stability Compartments 3 and 4, Damage to Centerline

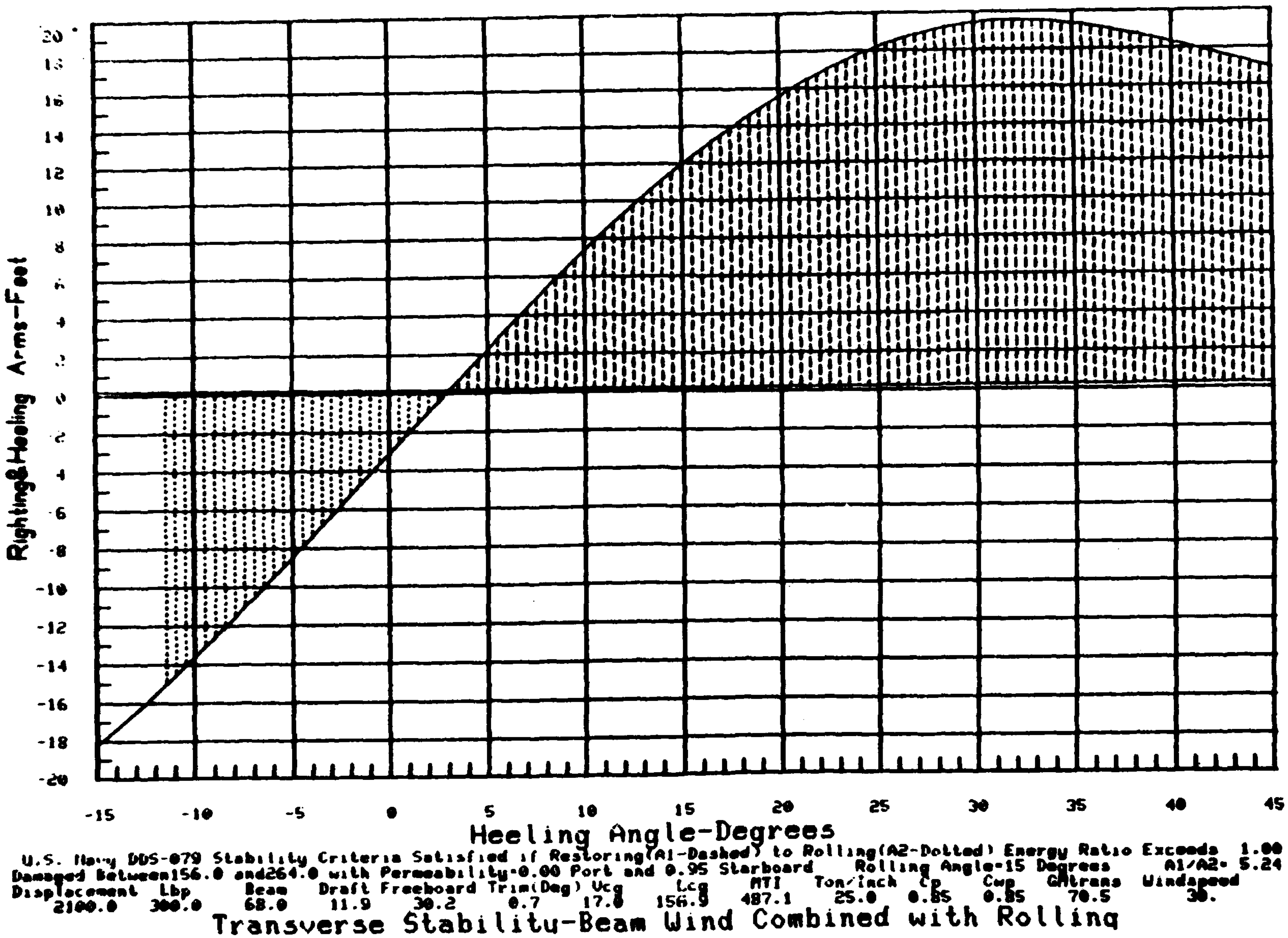


Figure 1.6-26. WHEC-SES Damage Stability Compartments 4 and 5, Damage to Centerline

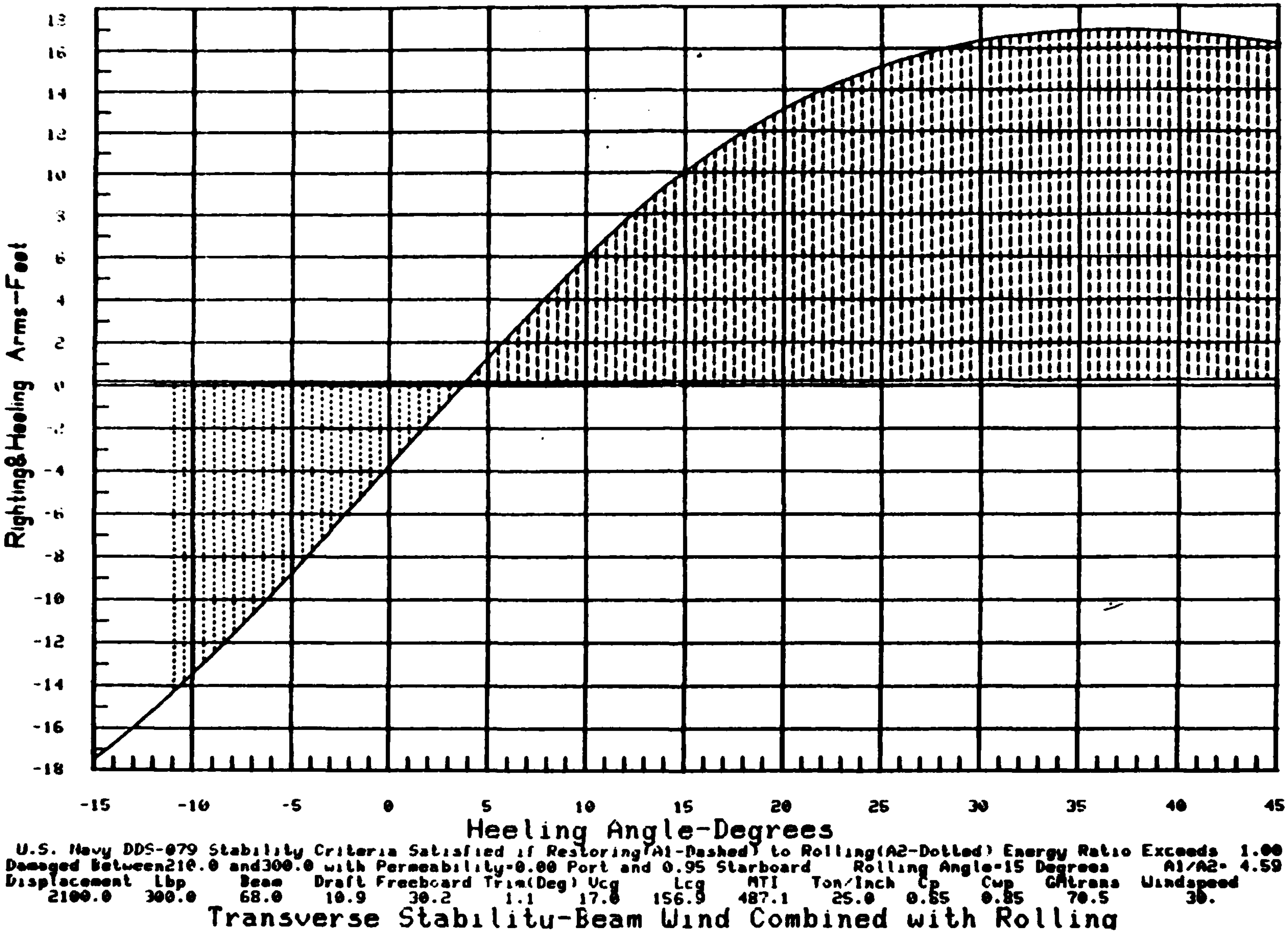


Figure 1.6-27. WHEC-SES Damage Stability Compartments 5 and 6, Damage to Centerline

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APPENDIX 2

DESIGN DESCRIPTION - WMEC-SES

1. INTRODUCTION

This appendix provides a description of a surface effect ship design concept developed to meet the requirements of the existing USCG-WMEC craft. The design concept is described in terms of layout drawings, tables, and text.

2. PRINCIPAL CHARACTERISTICS

The principal characteristics of the WMEC-SES are summarized in Table 2.2-1.

3. MISSION REQUIREMENTS

The mission requirements are summarized in Table 2.3-1.

4. SHIP CONFIGURATION

The WMEC-SES outboard profile and hull geometry are shown in Figures 2.4-1 and 2.4-2 respectively. The principal features of the major subsystems are discussed in the following paragraphs.

4.1 GENERAL ARRANGEMENT -- The general arrangement is shown in Figure 2.4-3. As shown in Figure 2.4-3, office and CPO living spaces, ship offices, and commissary spaces are located in the midship region of the Second Deck level. Longitudinal passageways, port and starboard, provide unobstructed access for ship operation and damage control.

Table 2.2-1. WMEC-SES - Principal Characteristics

Length Overall	280 Ft - 0 In
Length Cushion	252 Ft - 0 In
Breadth Overall	55 Ft - 0 In
Breadth Cushion	33 Ft - 4 In
Depth Main Deck	28 Ft - 0 In
Depth Cushion	20 Ft - 0 In
Full Load Displacement	1035 Long Tons
Maximum Speed (Maximum Continuous Power and SS 0)	35 Knots
Propulsion Machinery (High Speed)	Two SACM 20V240RVR Diesel Engines
(Low Speed)	Two MTU 12V396TB93 Diesel Engines
Propellers	Two Propellers
Lift Engines	Three MTU 12V396TB93 Diesel Engines
Lift Fans	Six Mixed Flow

Accommodations:

	Permanent Crew
Officers	12
CPO's	9
Enlisted Personnel	69
Total	90

Table 2.3-1. WMEC Design Requirements

A. Missions:

ELT - Enforcement of Laws & Treaties

SAR - Search and Rescue
MER - Marine Environmental Response
MP - Military Preparedness

B. Mission Equipment:

Stores (6.1 Ltons)
C^3 Navigation (15.6 Ltons)
MK 75, 76mm Gun w/ammo and MK 92 GMS (10.0 Ltons)
(2) 40mm MG's w/mounts and ammo (.5 Ltons)
(2) 50 cal MG's w/mounts and ammo (.5 Ltons)
(2) 6M RHI w/SPD (6.6 Ltons-(2)-19'x8'x4')
Helo Fuel (45 Flt Hrs - 12 Ltons)
(2) - 500 KW Generators
(1) - 400 KW Emergency Generator
SRBOC (Super rapid blooming offboard chaff)

Water (14.6 Ltons)
Crew (21.6 Ltons)
LAMPS I
COMDAC - Automated CIC
6000 Gal/Day Evaporator
Towed Array Sonar
AN/SLQ-32

C. Speed vs. Sea State:

30 kts/SS2
25 kts/SS3
20 kts/SS4

35 kt dash capability (calm water)

D. Endurance:

21 days (504 hrs)

24 hrs @ top speed
480 hrs @ cruise speed
10% reserve fuel

E. N/A - to be governed by (D.)

F. Operating Environment:

Operating in temperate or southern waters (no ice capability) within 400 miles of land.

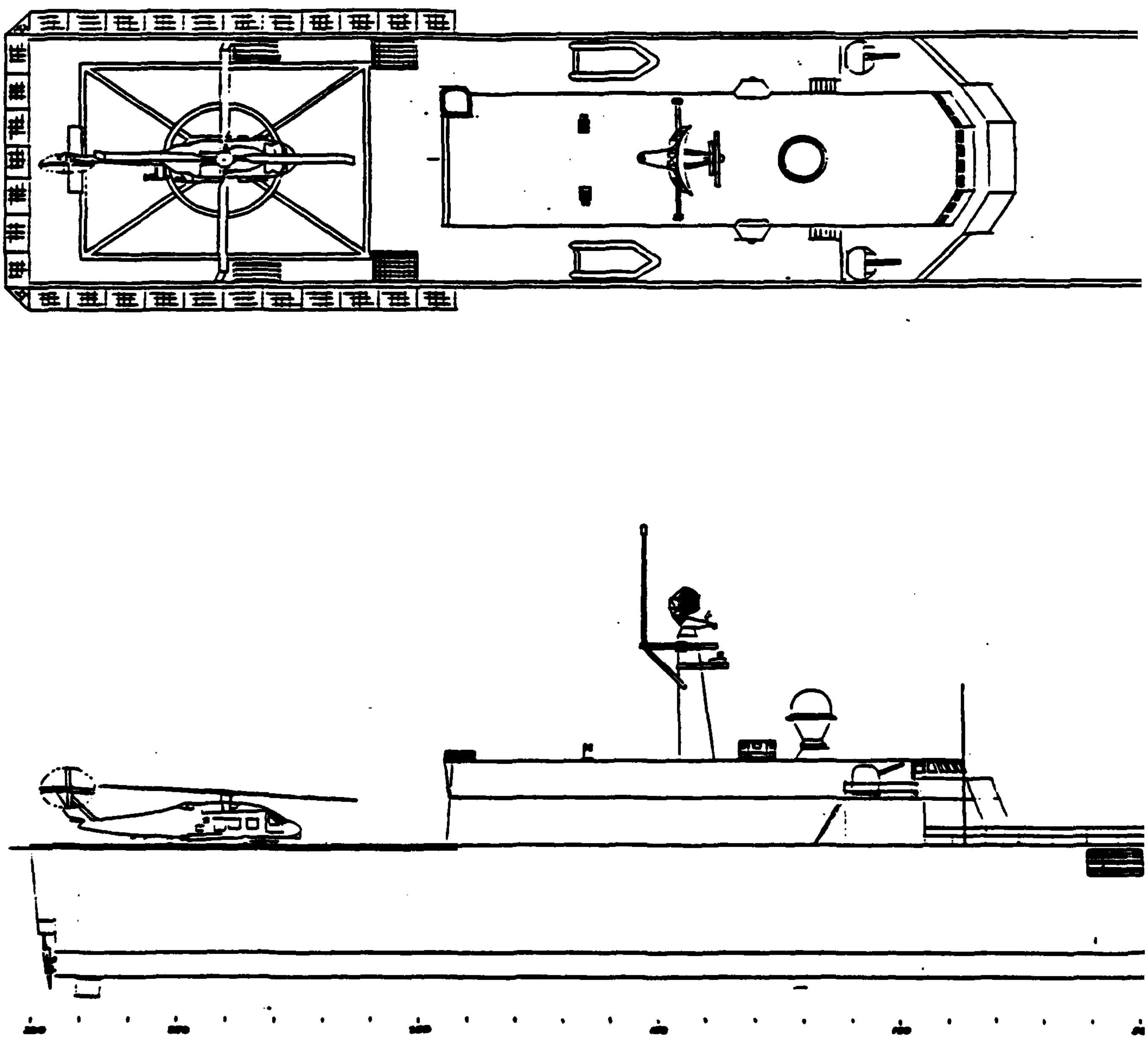
G. Complement:

90 Permanent Crew

12-Officers
9-CPOs
69-Enlisted

H. Other Design Features:

1. External Fire Fighting Capability (125 psi)
2. Available ride control systems for improving ride quality
3. Ability to meet USN 100 kt wind heel criteria
4. Survivability in SS6
5. Expect 80% operation on-cushion
6. 15-Yr hull life
7. Aluminum or steel construction
8. HIFR capability
9. Rudddr roll stabilization
10. HH-65A operations and hanger capable



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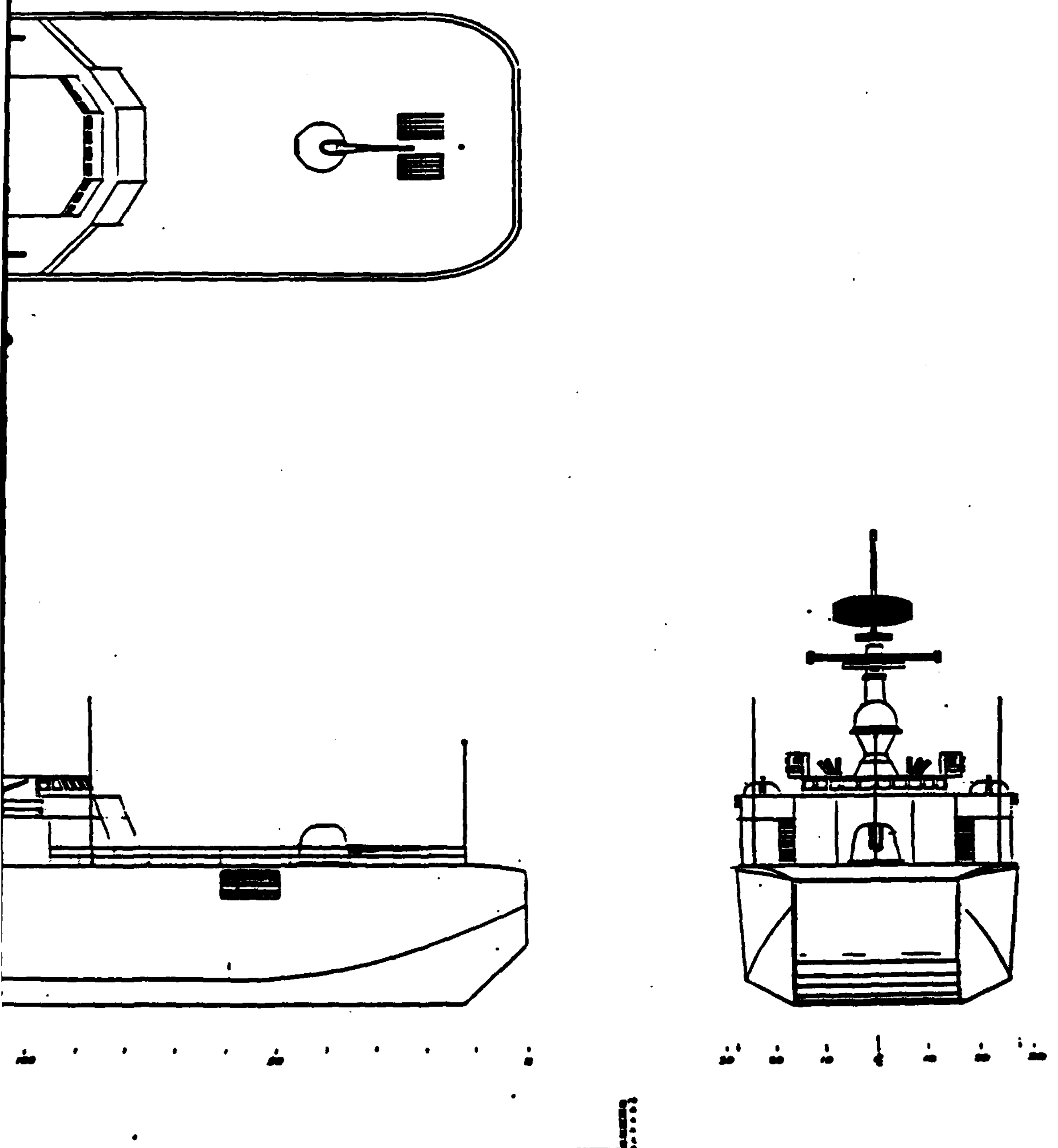
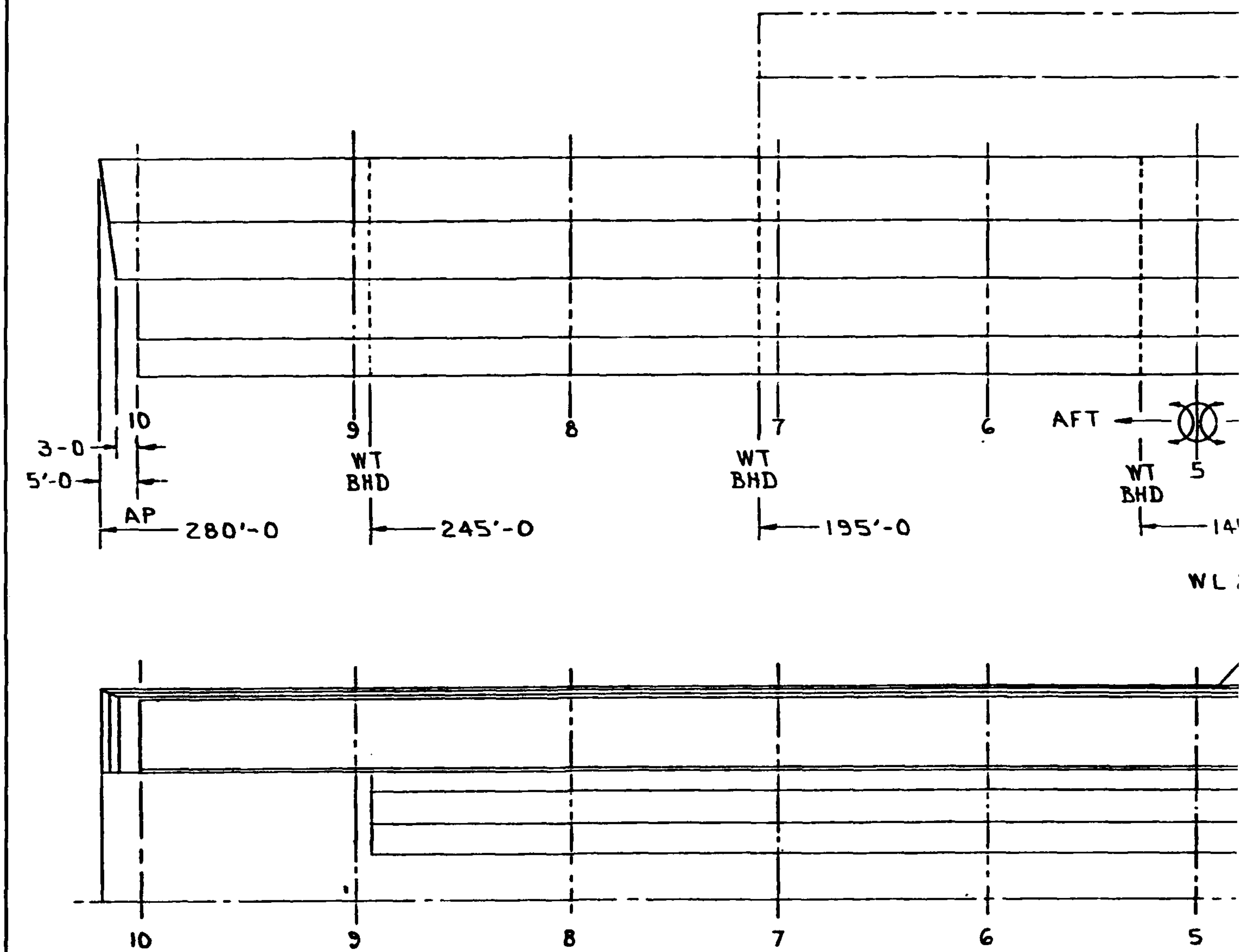
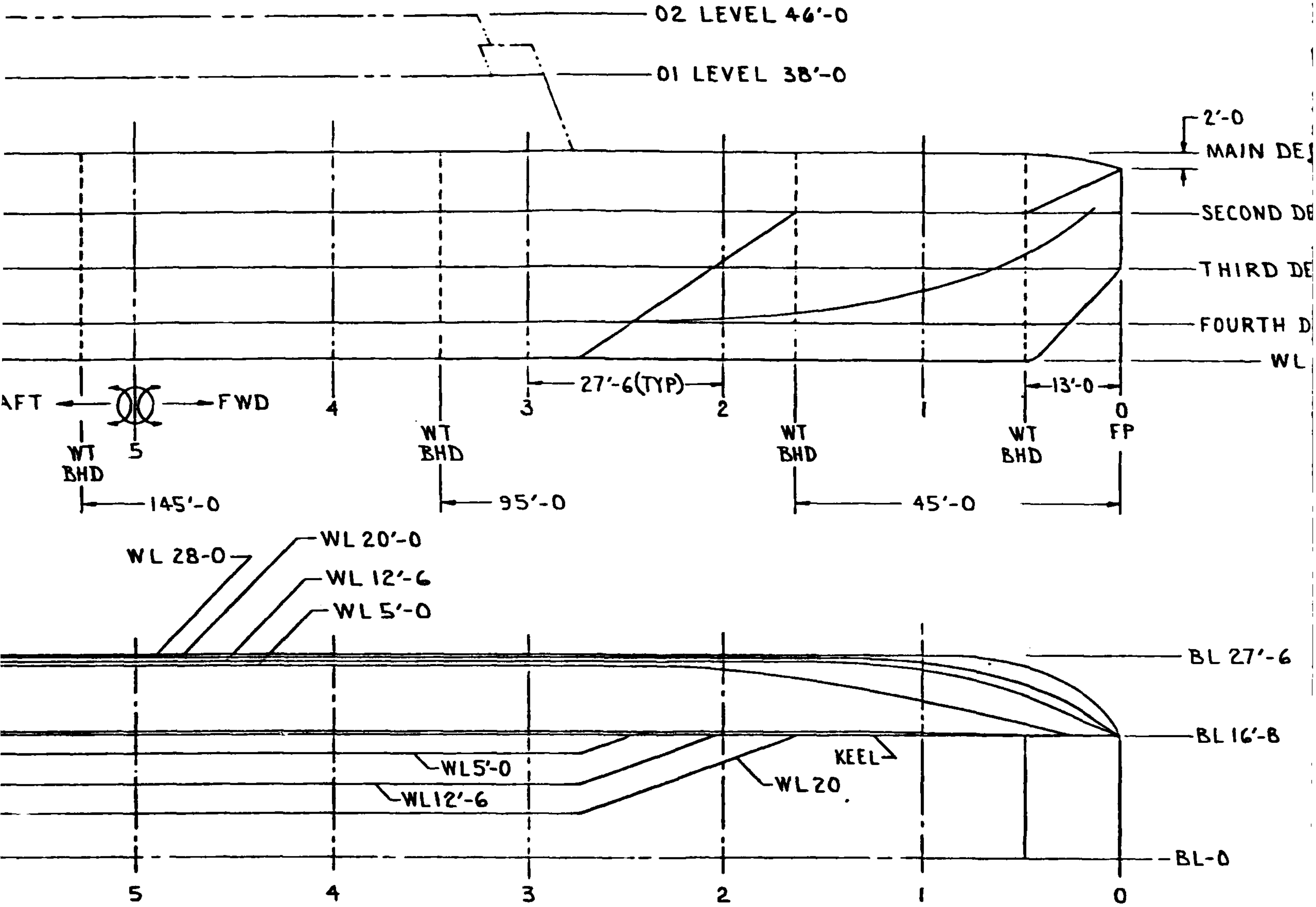


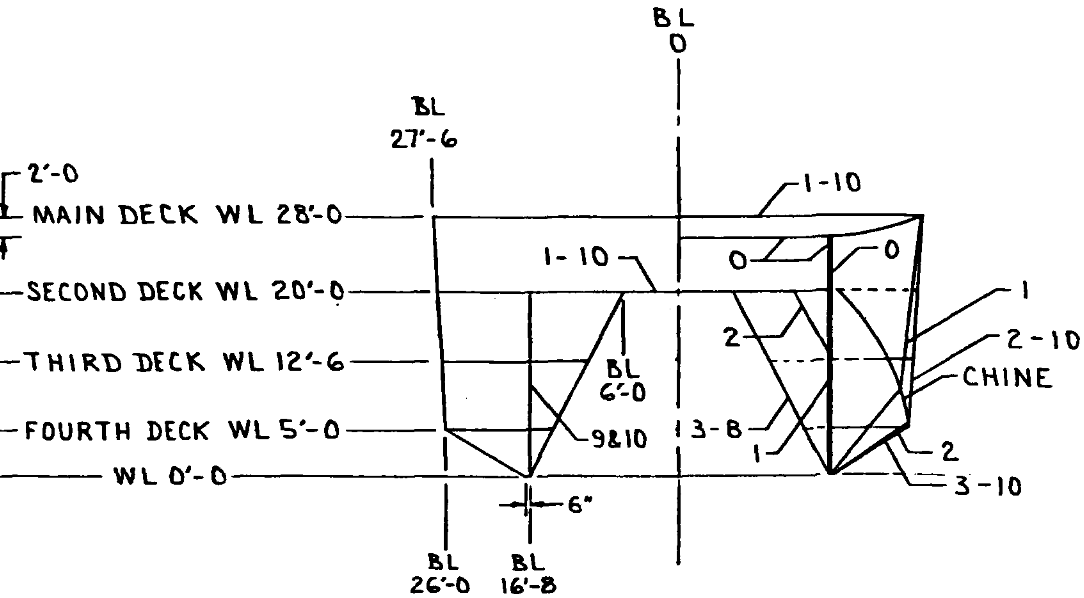
Figure 2.4-1
WMEC-SES
Outboard Profile



10
9
8
7
6
AFT
5
3-0
5'-0
WT
BHD
WT
BHD
WT
BHD
AP
280'-0
245'-0
195'-0
WL
10
9
8
7
6
5



02 LEVEL 46'-0
01 LEVEL 38'-0
2'-0
MAIN DE
SECOND DE
THIRD DE
FOURTH D
WL
27'-6(TYP)
13'-0
AFT
FWD
4
3
2
1
0
FP
WT BHD
5
WT BHD
WT BHD
WT BHD
145'-0
95'-0
45'-0
WL 28-0
WL 20'-0
WL 12'-6
WL 5'-0
BL 27'-6
BL 16'-8
KEEL
WL5'-0
WL12'-6
WL 20
BL-0
5
4
3
2
1
0



BL 27'-6

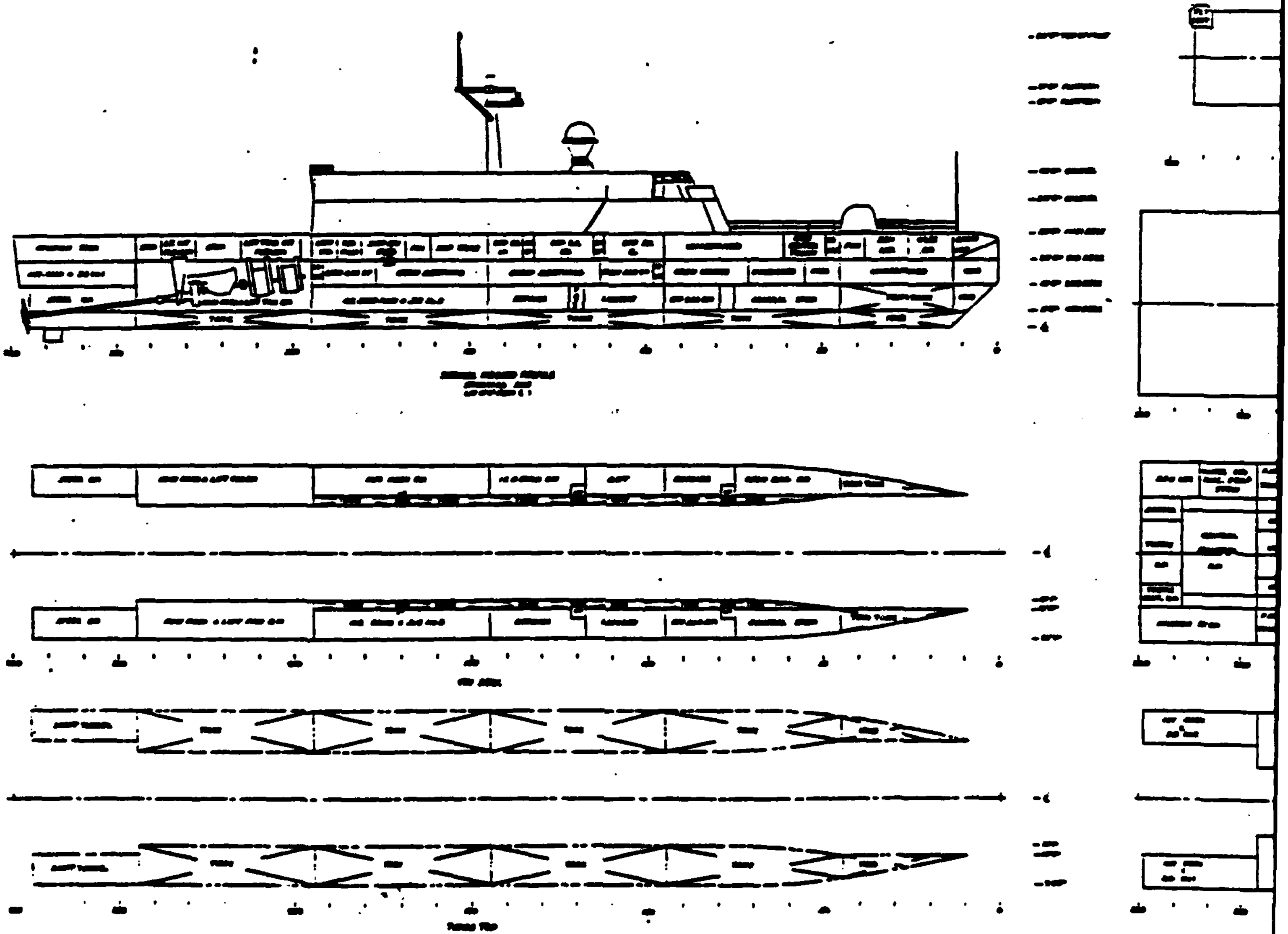
BL 16'-8

BL-0

PRINCIPAL PARTICULARS

LENGTH OVERALL	280'-0
LENGTH B.P.	275'-0
BEAM MOLDED	55'-0
CUSHION LENGTH	252'-0
CUSHION BEAM	33'-4
CUSHION DEPTH	20'-0
DEPTH TO MAIN DECK	28'-0
DESIGN DISPLACEMENT	1035 L TONS
DRAFT HULLBORNE	8'-4

Figure 2.4-2. WMEC-SES Hull Lines



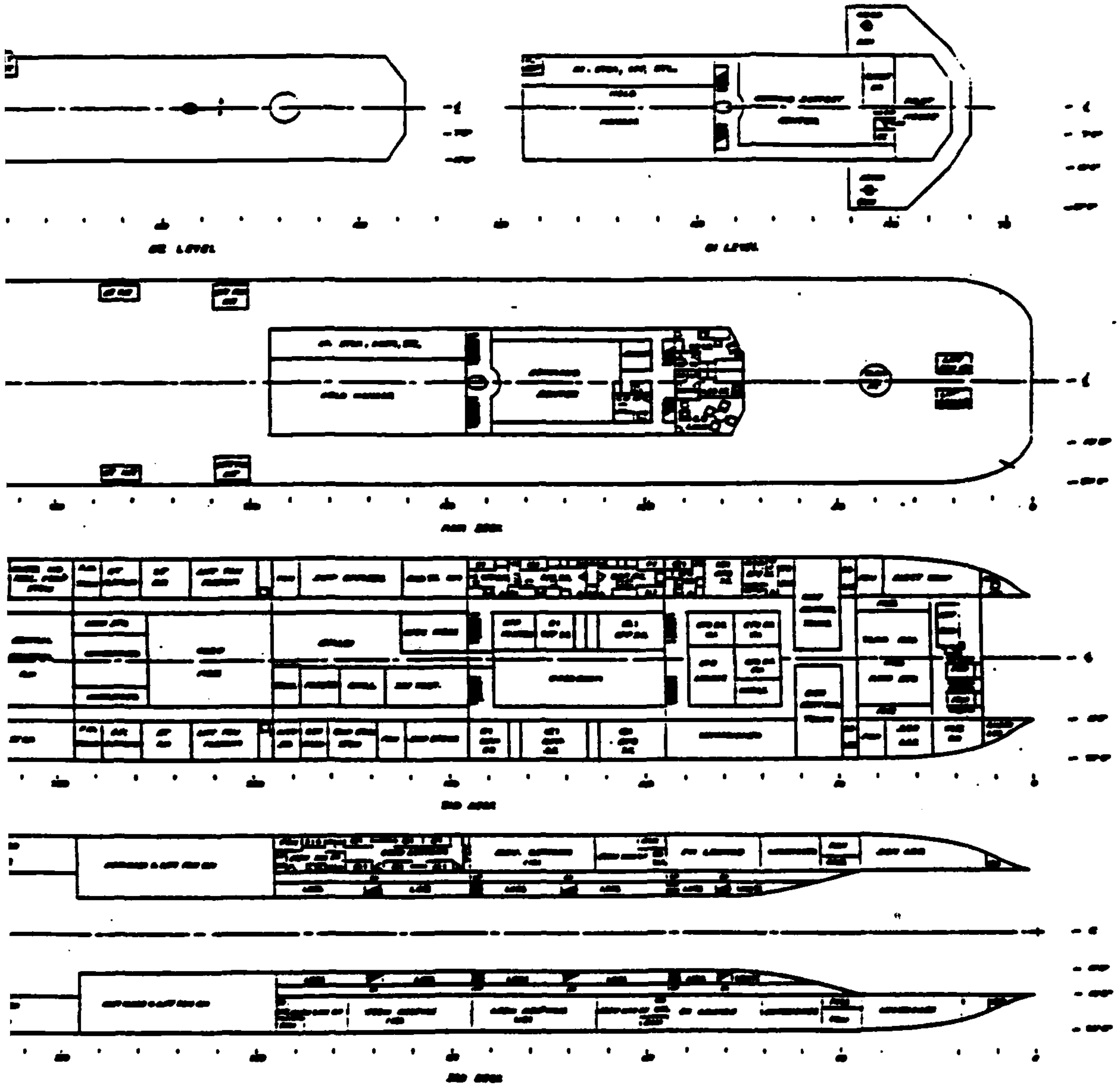


Figure 2.4-3
WMEC-SES
General Arrangement

Accommodation spaces for the senior officers is provided on the Main Deck level. The Command Center is located on the Main Deck immediately aft of the senior officer living area. A helicopter hangar is provided immediately aft of the Command Center.

The Pilot House and Command Support Center are located on the 01 level immediately above the senior officer living area and Command Center, respectively. Berthing for enlisted personnel and other enlisted personnel living spaces are located port and starboard on the Third Deck level.

The habitability space deck area allocations and other hull volume allocations are summarized in Table 2.4-1. For comparison, the space allocations provided in existing WMEC ships are also shown in Table 2.4-1.

4.2 HULL STRUCTURE -- The hull is constructed of all-welded, high strength, 5000 series, marine grade aluminum alloy. The structural arrangement is shown in Figure 2.4-4. The structural design criteria and the shear and bending moment envelopes derived for the structural design are shown in Figures 2.4-5 and 2.4-6, respectively.

4.3 MACHINERY ARRANGEMENT -- The arrangement of the propulsion and lift machinery is shown in Figure 2.4-7. As shown in Figure 2.4-7, the propulsion engines, aft lift engines, and aft lift fans are located port and starboard in the sidehull regions aft. The forward lift engines and fans are located on the forward region of the second deck. The arrangement shown was selected to provide the maximum isolation of the machinery from habitability spaces within the constraints of ship size and other arrangement requirements. The machinery isolation provided by the arrangement coupled with the installation of vibration isolation mounts for all machinery and acoustical treatment of machinery space boundaries should ensure low levels of noise and vibration in all habitability spaces.

The cushion seal installation consists of a transversely stiffened membrane (TSM) bow seal and a multiple loop bag stern seal. Both bow and stern

Table 2.4-1. WMEC-SES - Deck Area and Hull Volume Allocations

	SPACE DESCRIPTION	WMEC-SES		EXISTING CRAFT			
				210 FT WMEC		270 FT WMEC	
		FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
BERTHING	CO Cabin	269	269	270	270	180	180
	XO	148	148	99	99	105	105
	EO	100	100	91	91	105	105
	Officer	1050	116.7	597	66.3	612	68
	CPO	524	58.2	276	30.7	379	42.1
	EM	1200	17.4	1566	22.7	1730	25.1
SANITARY	CO	30		32		28	
	XO	30		28		24	
	EO	30		28		24	
	Officer	150		191		74	
	CPO	95		70		124	
	EM	800		368		454	
MESS	Wardroom	660		256		338	
	CPO Mess	170		144		135	
	CPO Lounge	192					
	EM Mess	788		501		565	
	EM Lounge	456				394	
COMMISSARY	Officer Pantry	110		75		-	
	Galley	478		260		332	
	Scullery	77		70		90	
	Chill	115		48			
	Freeze	100		46		204	
	Dry Provisions	225		96			
	Ship Service	160		20		75	
	Laundry	207		198		135	
	Barber Shop	84		-		-	
	Sea Bags	390		-		183	
MED.	Medical Facility	170		40		62	
	TOTAL	8808		5370		6352	

Table 2.4-1. WMEC-SES - Deck Area and Hull Volume Allocations (Cont'd.)

SPACE DESCRIPTION		WMEC-SES		EXISTING CRAFT			
				210 FT WMEC		270 FT WMEC	
		FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
	Pilothouse	371		260		312	
	Chart Room	112		9		21	
	CIC	712		168		-	
	Sensor Room and Command Support Center	813		-		1032	
	Communication Center	-		-		624	
	Radio Room	-		168		-	
	IC and Gyro	231		180		110 (Gyro)	
	Code Room	-		72			
	Flight Control Station	25		-		13	
	TOTAL	2264		857		2112	
	Magazines	475		100		397	
	TACTAS Equipment Room	228		-		100	
	TACTAS Control Room	84		-		-	
	Helo Hangar	1372		-		380	
	Aviation Stores, Off, etc	1107		-		377	
	Armory	64		14		35	
	TOTAL	3330		114		1289	
	Unassigned	1161					

OTHER EQUIPMENT:

Water

Required = 14.6 Tons

Available (Tanks 1 & 2) = 24 x .95 x .98 = 22.4 Tons

Fuel *

Required = 300 + 12.1 = 312.1 Tons

Available

Tanks (1 & 2) = 14.6 x .95 x .98 = 13.6 Tons

Tanks (3 & 4) = 30.2 x .95 x .98 = 28.1 Tons

Tanks (5, 6, 7, 8, 9, 10, 11 & 12) = 165.6 x .95 x .98 = 154.2 Tons

Tanks (11 & 12) = 39 x .95 x .98 = 36.3 Tons

Tanks (13, 14, 15, 16, 17, 18, 19 & 20) = 226.8 x .95 x .98 = 36.3 Tons / 211.2 Tons

* The values given are ship and helo fuel estimates (Figure 4.2-2.)

479.7 Tons

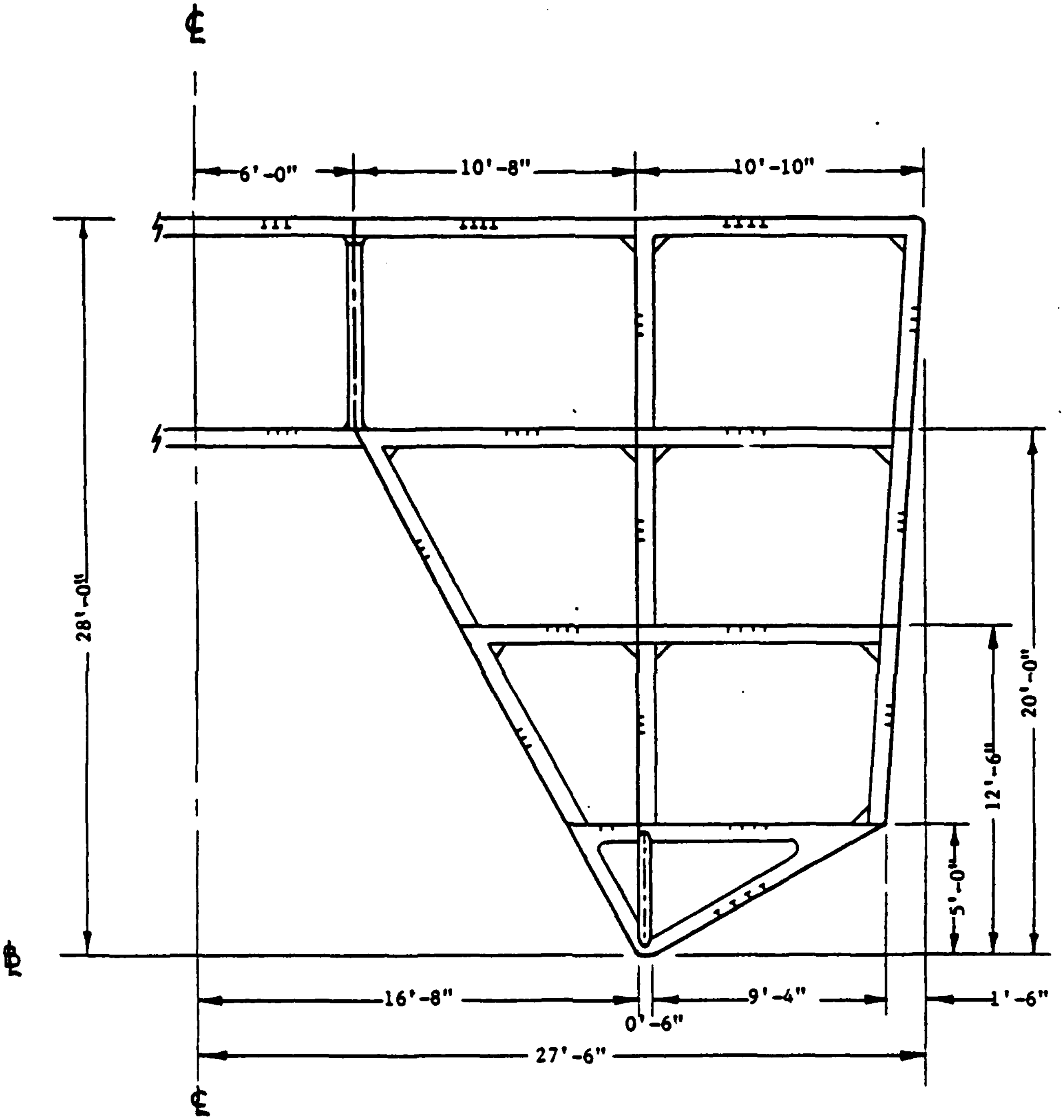


Figure 2.4-4. WMEC-SES - Typical Midship Frame Section

SLAM PRESSURES ARE NOT COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS (OTHER THAN SLAMMING) ARE COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS INCLUDE DECK
LIVE LOADS: 75 PSF (TOP OF DK HSE)
150 PSF (LIVING, OFFICE SPACES)
200 PSF (MACHINERY SPACES)

USE 50% OF SLAM PRESSURE FOR FRAME DESIGN

SAFETY FACTORS	YIELD	ULT.
HULLBORNE + LOCAL LOADS	1.2	1.5
CUSHIONBORNE + LOCAL LOADS	1.2	1.5
SLAMMING PRESSURES	1.0	1.2

PERMANENT SET TO A MAXIMUM OF PLATE THICKNESS IS ALLOWED

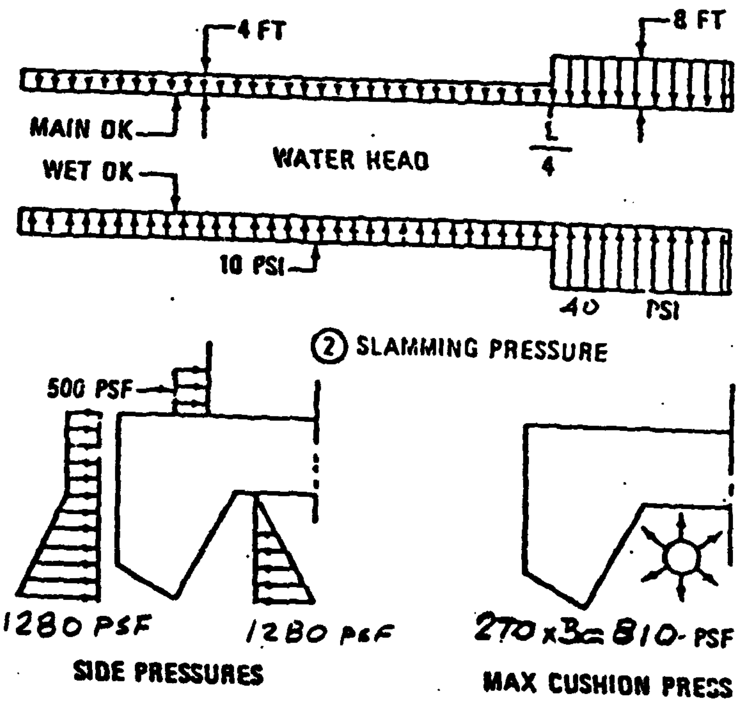
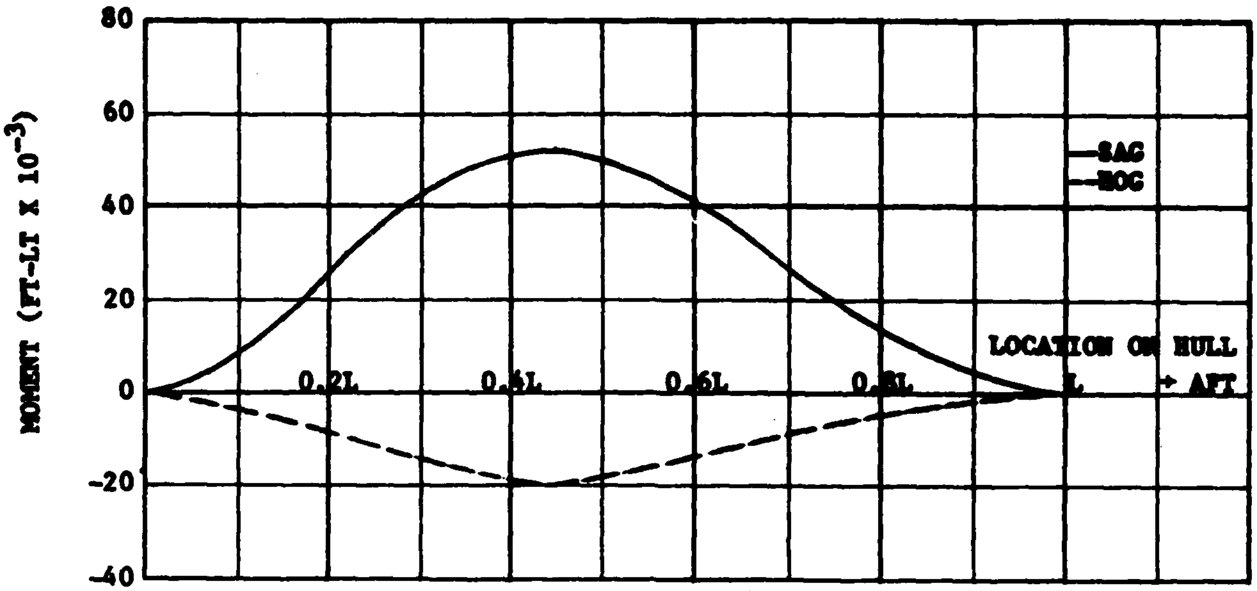
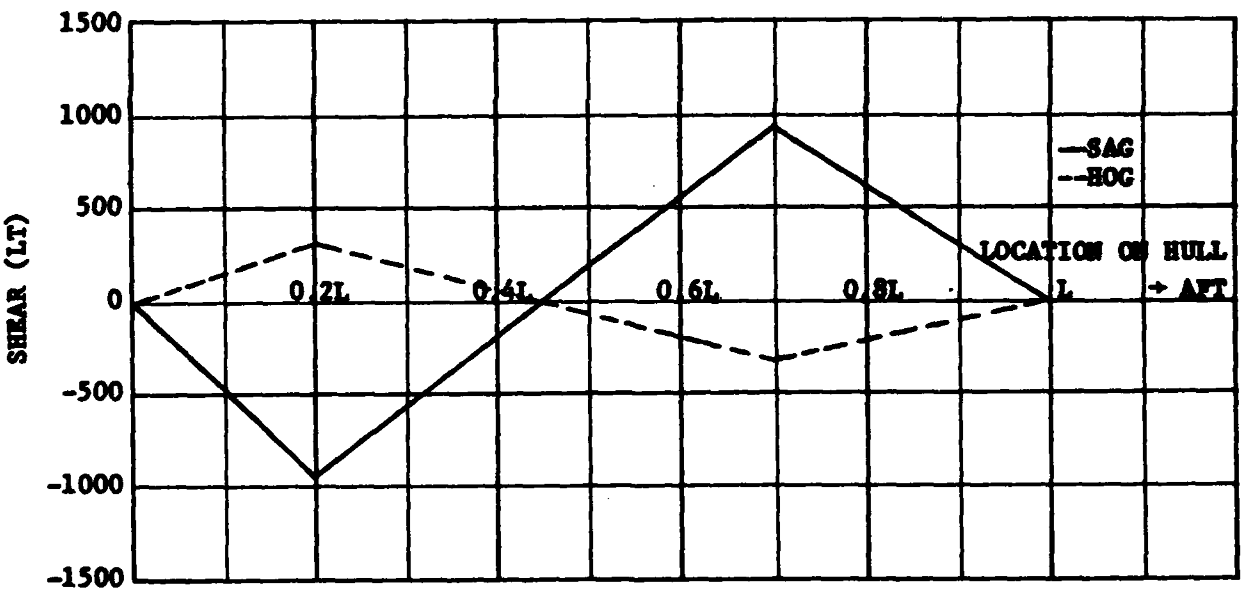


Figure 2.4-5. WMEC-SES Hull Design Criteria



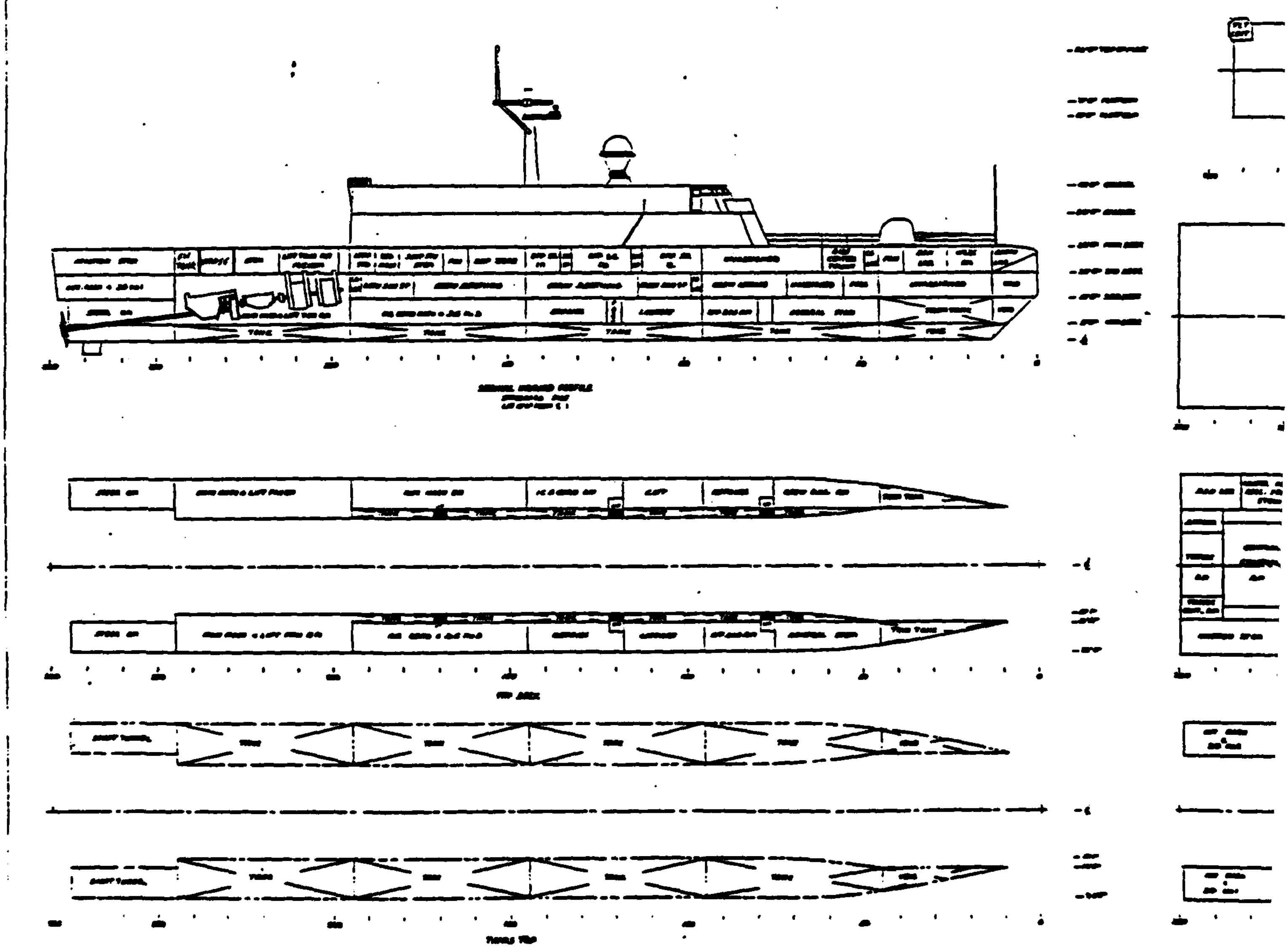
HULLBORNE BENDING MOMENT



HULLBORNE SHEAR

Safety Factors - SF Yield = 1.2
SF ULT = 1.5

Figure 2.4-6. WMEC-SES Design Shear and Bending Moment Envelopes



2

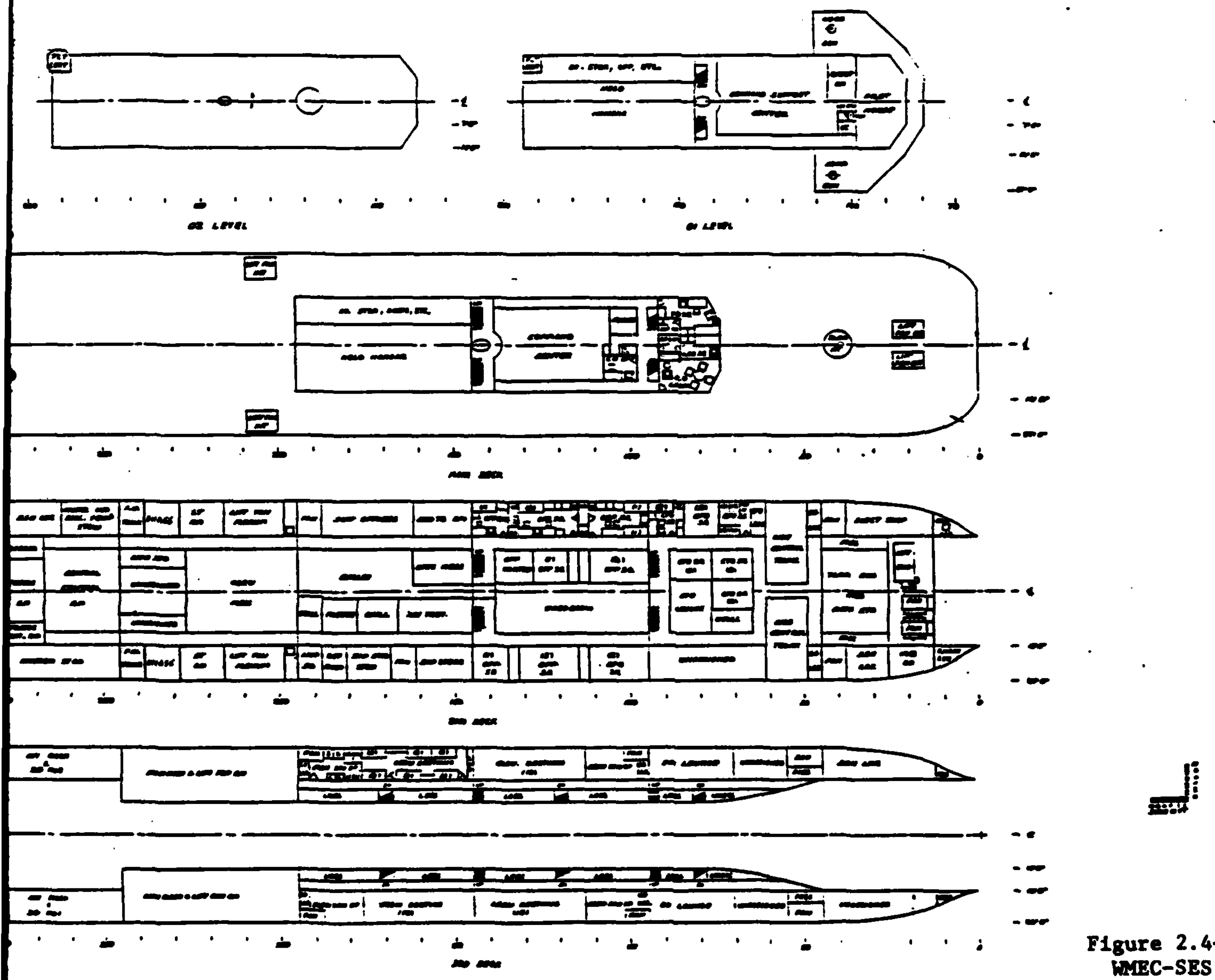


Figure 2.4-7
WMEC-SES
Machinery Arrangement

seals are provided with retraction systems. The bow seal and stern seal are shown in Figures 2.4-8 and 2.4-9, respectively. The seal materials are listed in Table 2.4-2.

4.4 ELECTRICAL SYSTEM -- The electrical power system consists of three 500 KW, 60 Hz diesel generators connected in a ring bus distribution system. The power provided by the two operating diesel engines is adequate to satisfy the ship's electrical power requirements under all operating conditions. The third generator provides standby power. Transformer rectifiers of a type proven in service aboard Navy ships are used to provide 28 volt DC for control and actuator power, as required. A battery bank is used to provide emergency and/or uninterruptible power. Two solid state 60 Hz/400 H2 frequency convertors are employed to provide 400 Hz power as required with one operational and the other on standby under normal operating conditions. A diagram of the electrical power distribution concept is shown in Figure 2.4-10.

4.5 COMMAND COMMUNICATION AND CONTROL -- Four command communication and control spaces are provided:

1. Pilot House located on the 01 level.
2. Command Support Center located on the 01 level immediately aft of the pilothouse.
3. Command Center located on the main deck amidships.
4. Central Control Room located on the main deck aft.

The Pilot House serves as the primary control station for ship maneuvering, navigation and collision avoidance. Limited control of propulsion and lift machinery is provided in the Pilot House to the extent required for ship handling.

The Command Center and the Command Support Center are the primary centers for tactical command and for exterior and interior communications.

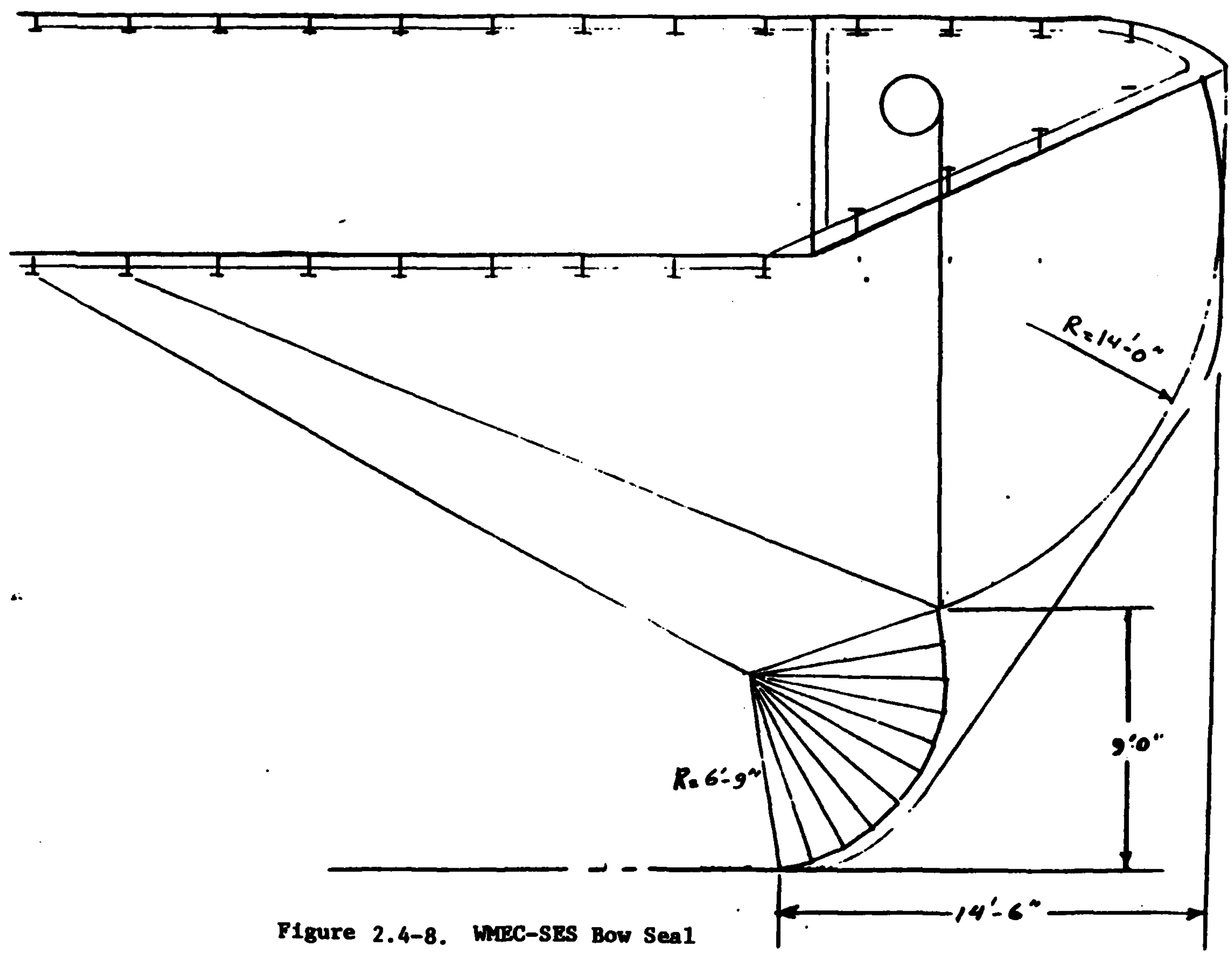


Figure 2.4-8. WMEC-SES Bow Seal

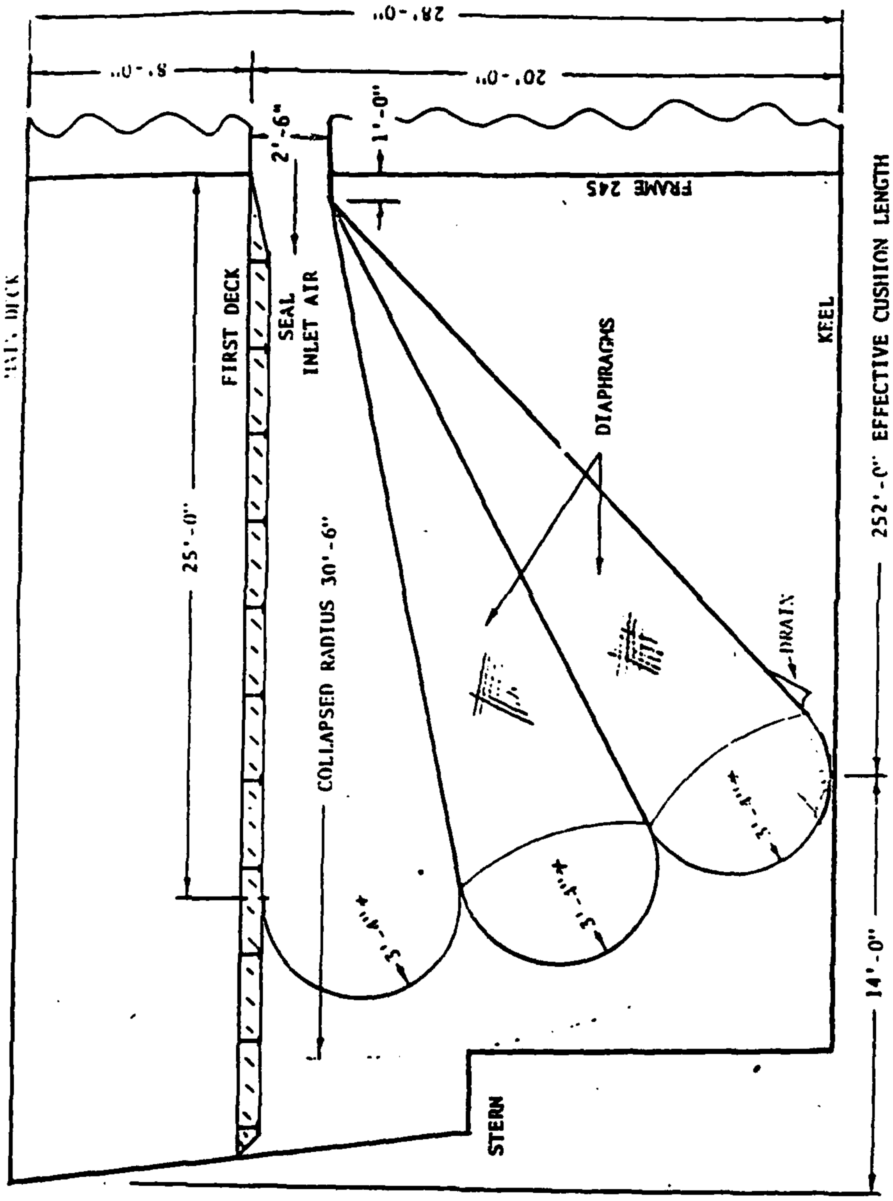


Figure 2.4-9. WMEC-SES Stern Seal

Table 2.4-2. WMEC-SES Seal Materials

MATERIAL CHARACTERISTIC	BAG		PARASOL (NOTE (1))
	BOW	STERN	
Fabric Type	Nylon 3x3 (Basket Weave)	Nylon 3x3 (Basket Weave)	Nylon 3x3 (Basket Weave)
Coating Type	Neoprene Base Rubber	Neoprene Base Rubber	Neoprene Base Rubber
Material Weight	170 Oz/Yd^2	90 Oz/Yd^2	90 Oz
Tensile Strength: Warp	2400 ply	1240 ply	1240 ply
Tensile Strength: Fill	2400 ply	1280 ply	1280 ply
Minimum Tear Strength	>500 ply	>500 ply	>500 ply

<u>Note</u>:

1. Parasol stiffening elements (battens) have the following dimensions:

   Thickness = 1/8 In. to 3/16 In.

   Width = 1 In. - 1-1/2 In.

   Length ≈ 14 In.

   Batten material is glass reinforced plastic (Scotchply 1002). Fibers are unidirectional and parallel to the long side of the batten. Batten material properties are as follows:

Room Temp. and Dry	Flexural Strength =	165,000 psi
	Modulus in Flexure	5.3×10^6 psi
	Tensile Strength	160,000 psi
	Specific Gravity	1.8

2. Alternate seal coating may be Chemigum vinyl (Goodyear M-521) fabric type may be Goodyear H391.

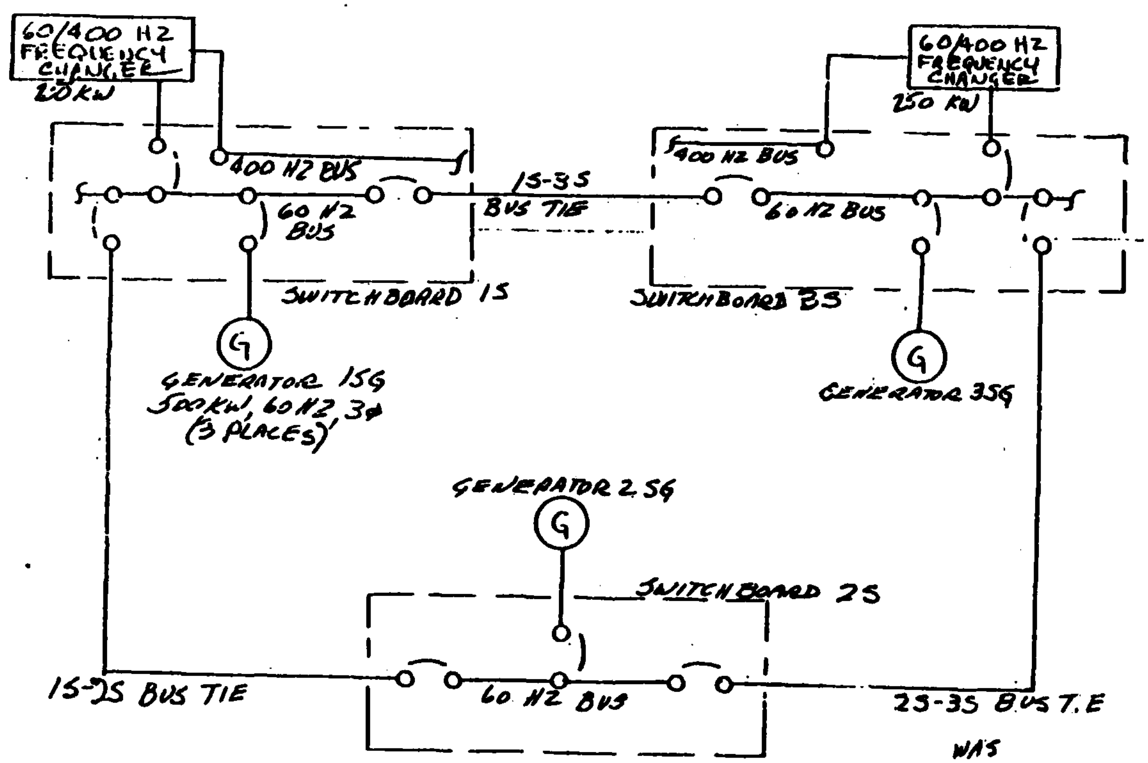


Figure 2.4-10. WMEC-SES Power System Distribution Diagram

The Central Control Room serves as the primary control station for all ship engineering and auxiliary support functions, including control and monitor capability for propulsion, lift, electrical and auxiliary machinery and damage control.

A certain amount of commonality is necessary between the control system functions assigned to the Pilot House and the Central Control Room. Vital ship functions, such as propulsion/lift engine throttle control and communications capability, are duplicated between the two spaces for reliability and safety. Additionally, certain alarms are presented in summary fashion at the Pilot House, with functional control of the monitored equipment being assigned to the Central Control Room.

Redundancy is provided for vital functions with (1) control consoles in The Pilot House and the Central Control Room, (2) spatially separated dual remote control paths, and (3) local control.

Navigation equipment is listed in Table 2.4-3.

5. WEIGHT ESTIMATE

The weight estimate is summarized in Table 2.5-1. The lightship weights shown in Table 2.5-1 were derived from parametric analyses of other SES designs and the use of catalog information for major equipment items. Weights for mission related equipment and variable load items were derived from the design requirements defined in Section 3.

6. PERFORMANCE

The performance characteristics in terms of power, speed, range, ride quality, hydrostatic characteristics and stability are summarized below.

6.1 SPEED, DRAG AND SEA STATE RELATIONSHIPS -- The speed, drag, and power relationships for cushionborne operation at various craft displacements in Sea States 0 and 3 are shown in Figures 2.6-1 and 2.6-2, respectively. The hullborne speed characteristics in Sea States 0 and 3 are shown in Figures 2.6-3 and 2.6-4.

Table 2.4-3. WMEC-SES Command, Communication and Control Equipment

NAVIGATION EQUIPMENT	COMMUNICATIONS EQUIPMENT
• RADAR (COLLISION AVOIDANCE) (TWO SYSTEMS) • LORAN-C • SATNAV • RDF • GYRO • FATHOMETER • SPEED LOG • WIND SPEED AND DIRECTION	• VHF (TWO SYSTEMS) • SSB-HF (TWO SYSTEMS) • INTERIOR COMMUNICATION • INTERIOR TELEPHONE

Table 2.5-1. WMEC-SES Weight Estimate

SWBS	ITEM	LONG TONS
100	Hull Structure and Seals	285.0
200	Propulsion and Lift Systems	100.0
300	Electric Power Generation and Distribution System	30.0
400	Command and Surveillance System	50.0
500	Auxiliary Subsystems	55.0
600	Outfit and Furnishings	60.0
700	Combat System	0
	Estimated Lightship (without margin)	580.0
	Design and Construction Margin (10%):	58.0
	Design Lightship	638.0
F10	F10 - Personnel	21.6
F21	F21 -	
F23	F23 - Ordnance Delivery Systems	5.0
F29	F29 - Mission Related Expendables	20.0
F30	F30 - Stores	6.1
F42	F42 - Helo Fuel	12.1
F42	F42 - Ships Fuel	300.0
F50	F50 - Liquids and Gases	14.6
/	Mission Related Equipment (Payload)	17.6
	Full Load Displacement (FLD)	1035.0

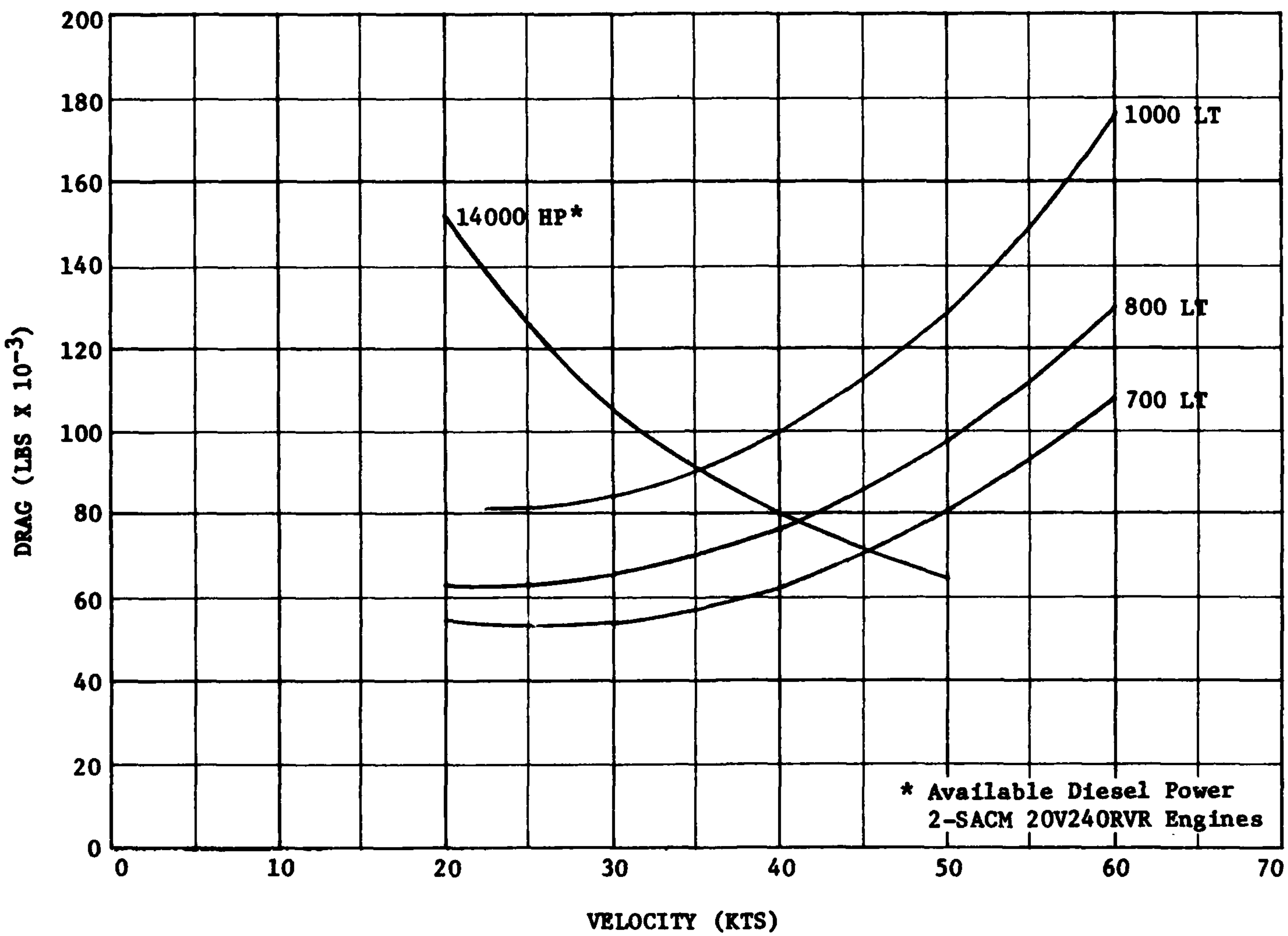


Figure 2.6-1. WMEC-SES Speed-Drag Curves Cushionborne - Sea State 0

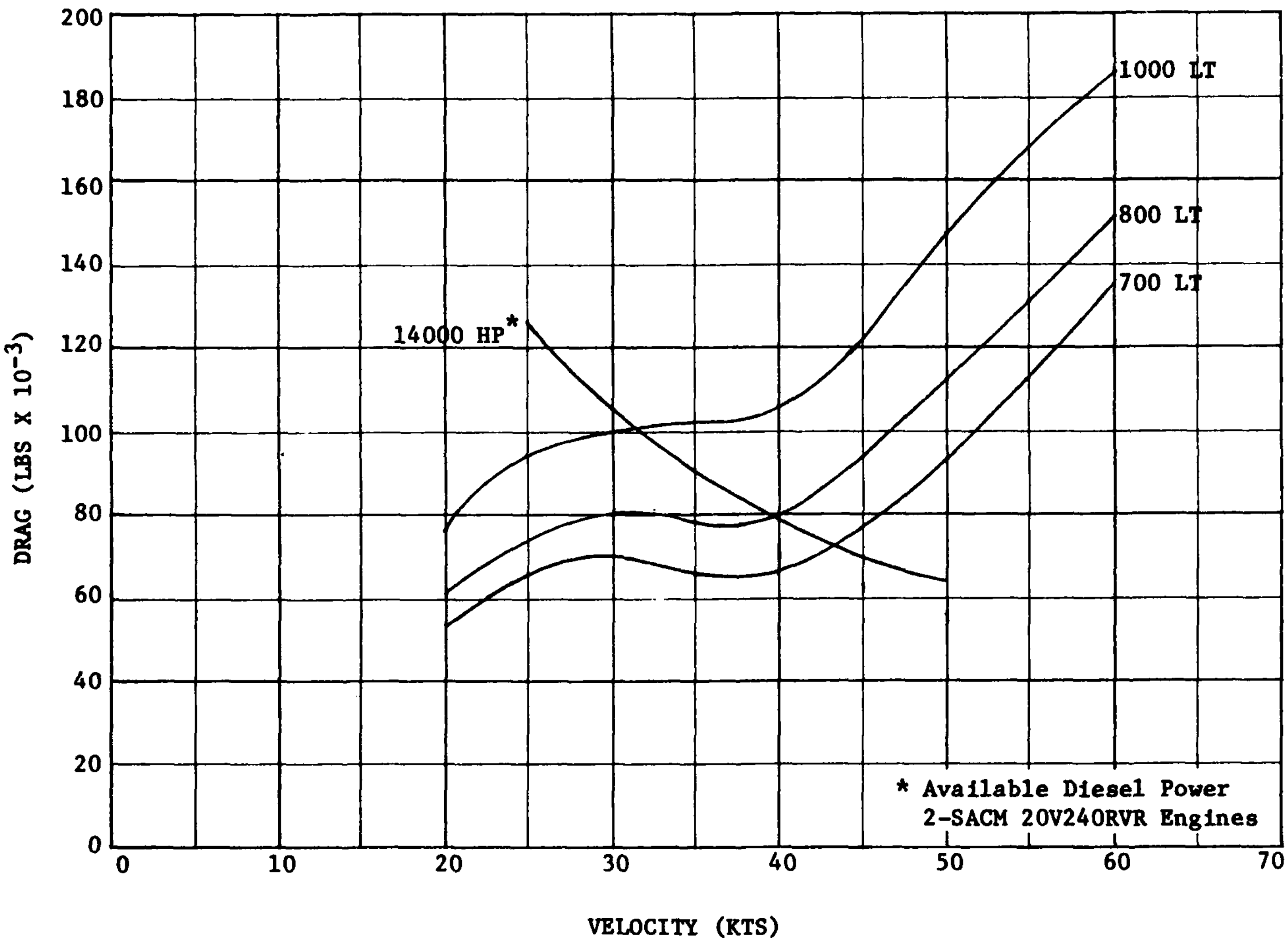


Figure 2.6-2. WMEC-SES Speed-Drag Curves Cushionborne - Sea State 3

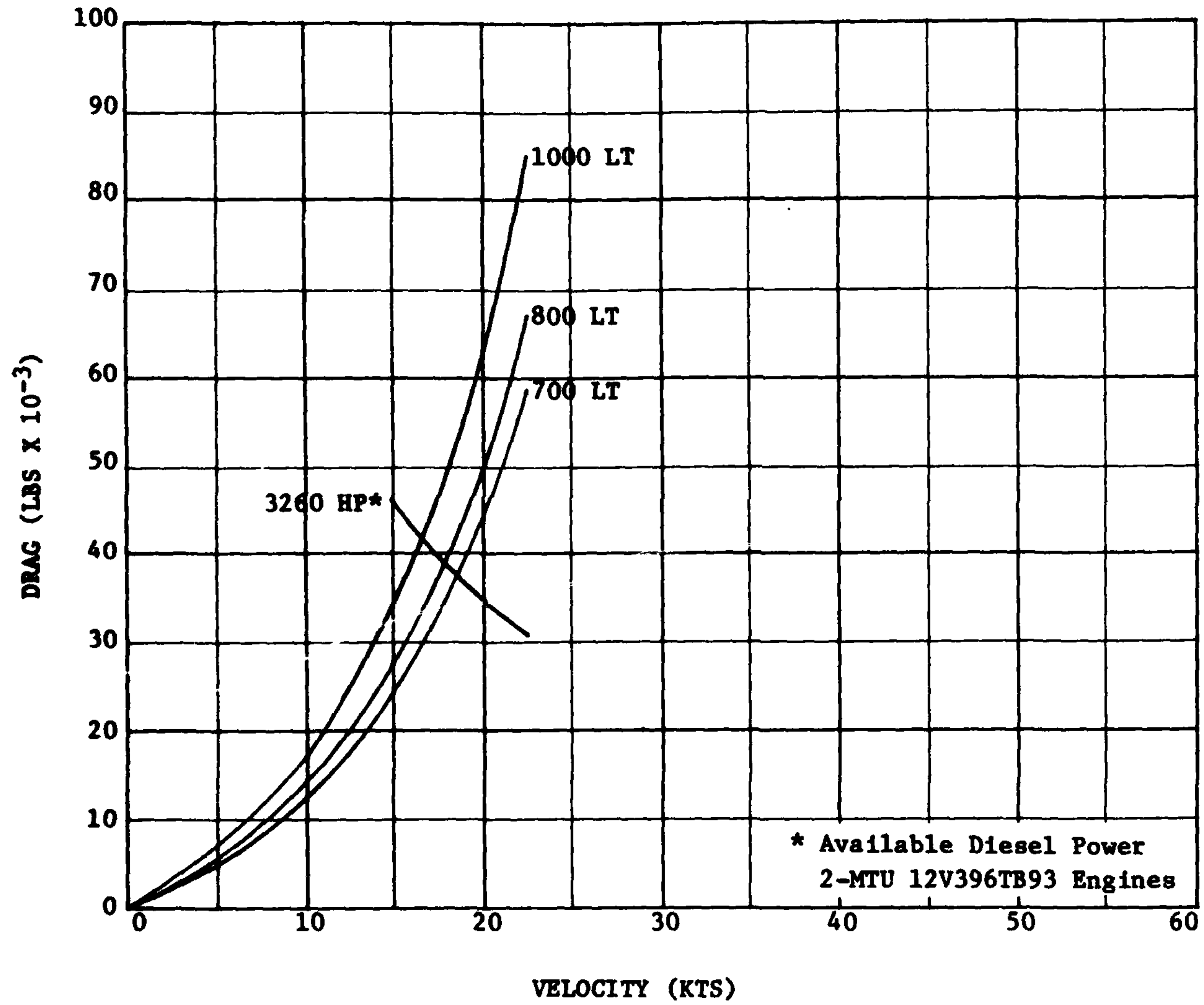


Figure 2.6-3. WMEC-SES Speed-Drag Curves Hullborne - Sea State 0

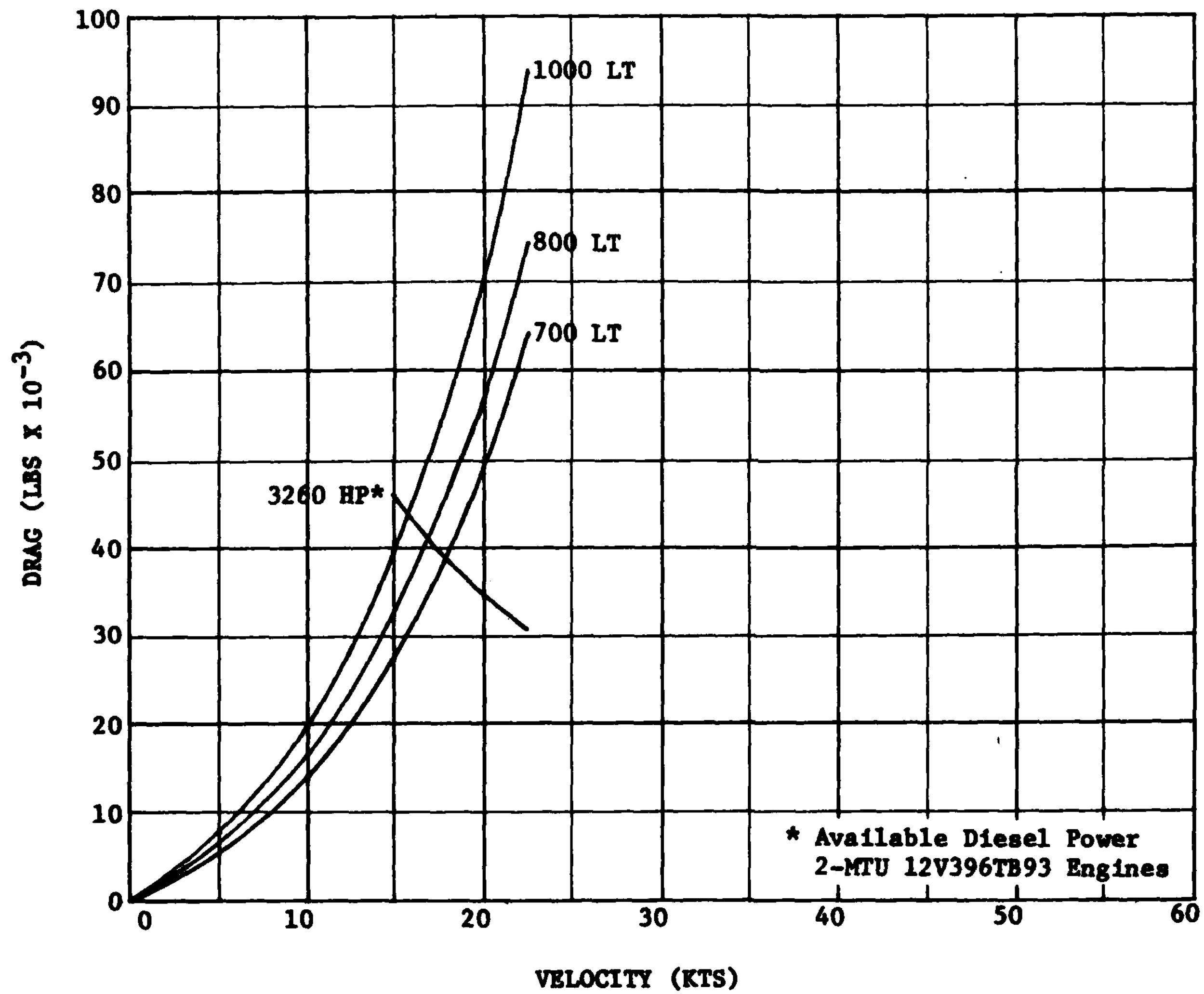


Figure 2.6-4. WMEC-SES Speed-Drag Curves Hullborne - Sea State 3

6.2 RANGE CAPABILITY -- The range capability for 35-knot cushionborne and 12-knot hullborne operation in Sea State 0 is shown in Figure 2.6-5.

6.3 SHIP MOTIONS AND RIDE QUALITY -- The ship motions characteristics at various speed and sea states relative to the U. S. Navy 30-minute and 4-hour ride quality criteria are shown in Figures 2.6-6 through 2.6-8. Note that the characteristics shown are representative of head sea conditions. Some improvement in ride quality may be accomplished by adjustment of the ship's heading to avoid the head sea condition.

6.4 HYDROSTATIC CHARACTERISTICS -- The hydrostatic characteristics, as derived from the lines drawing shown in Figure 2.3-2 are presented in Figures 2.6-9 through 2.6-15.

6.5 INTACT STABILITY -- The intact stability characteristics in the full load condition and burned out condition are shown in Figures 2.6-16 and 2.6-17, respectively. As shown in the figures, the craft satisfies the intact stability criteria of DDS 079-1, "Stability and Buoyancy of U. S. Naval Surface Ships", in both conditions.

6.6 DAMAGE STABILITY -- The assessment of stability under various conditions of two compartment damage is shown in Figures 2.6-18 through 2.6-29. As shown, the craft satisfies the requirements of DDS 079-1 under all damage conditions investigated. The assessment was based upon an intact full load displacement condition. A permeability of ninety five percent was assumed for all areas subject to flooding.

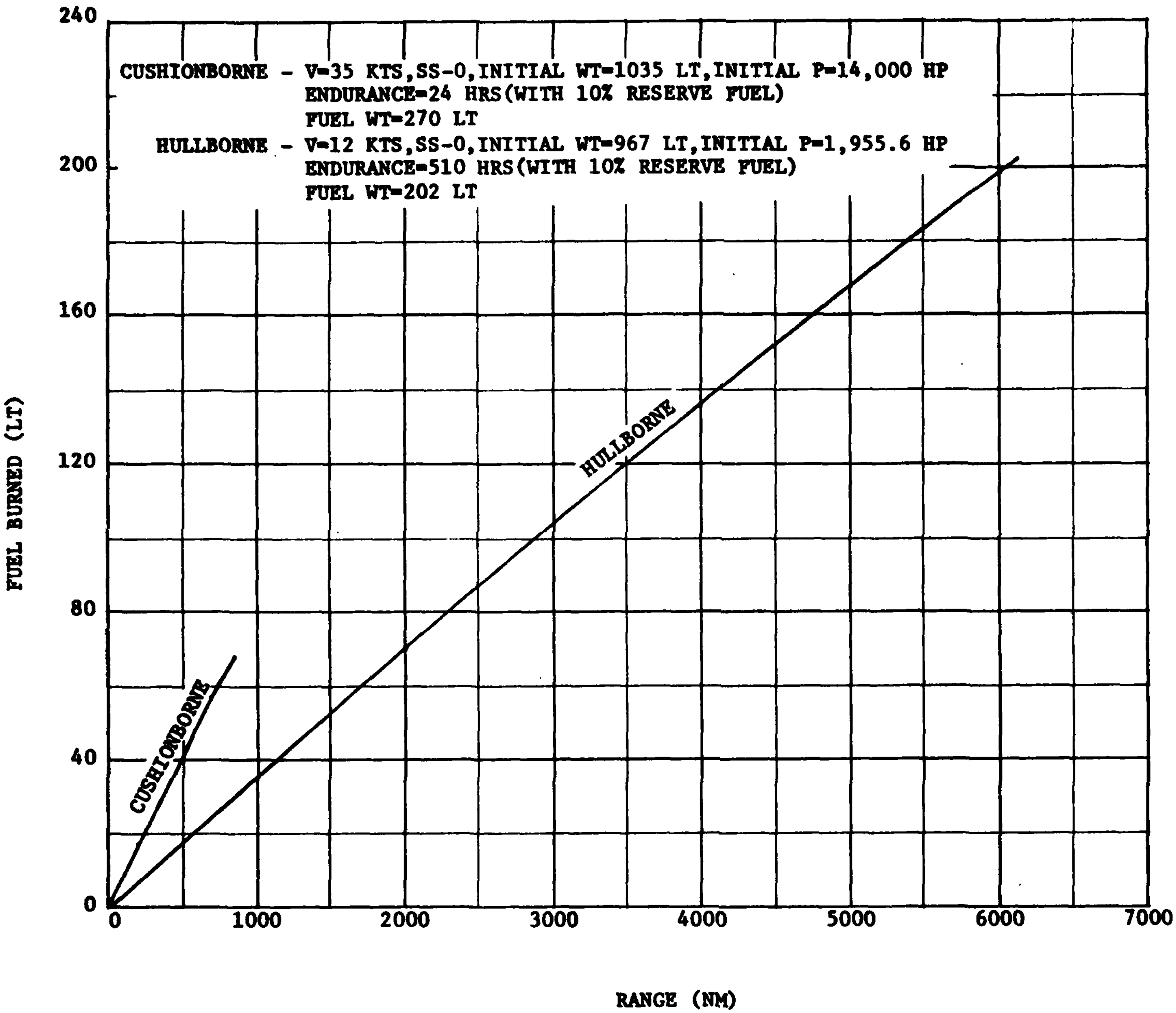


Figure 2.6-5. WMEC-SES Range Capability

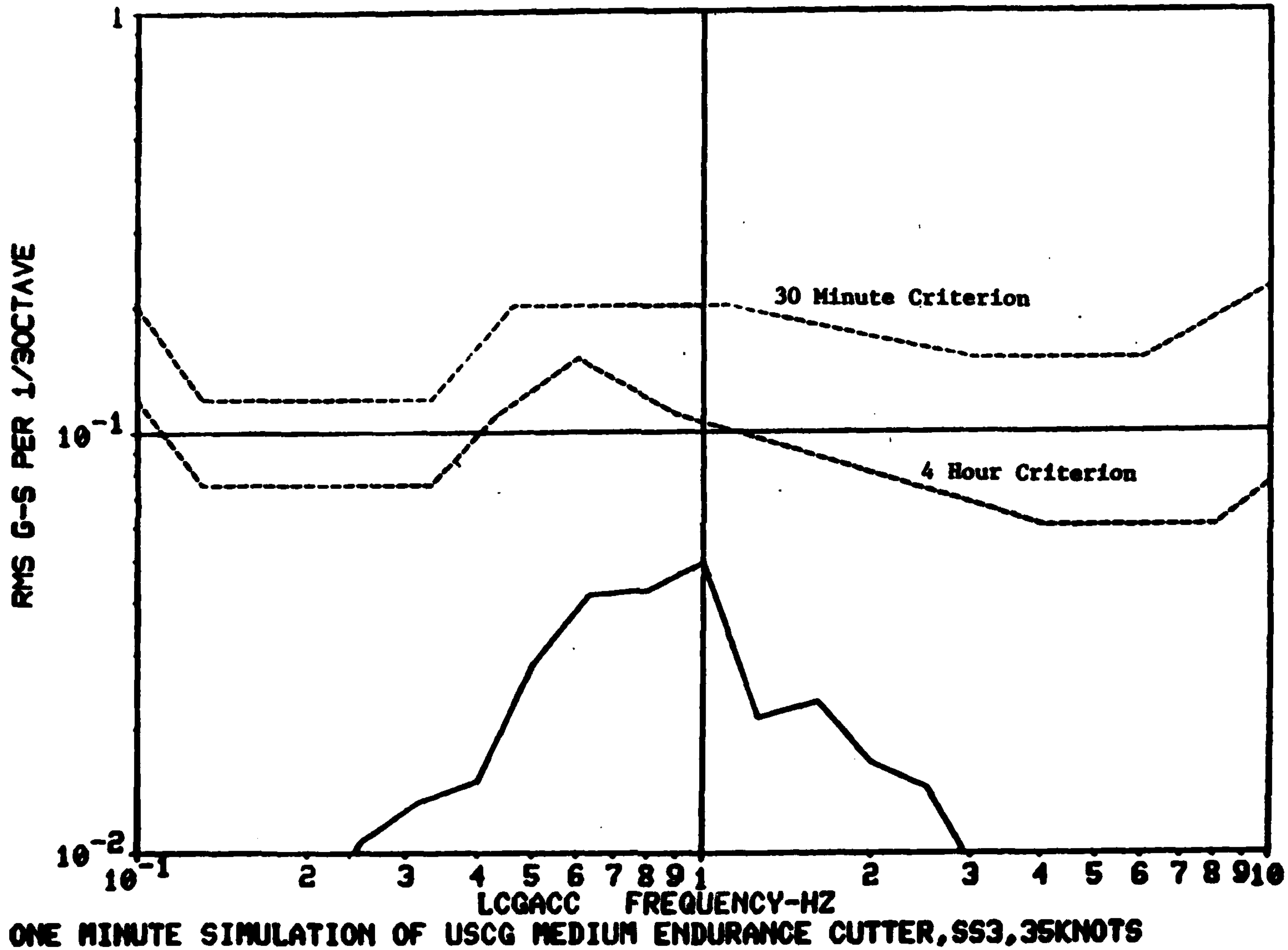


Figure 2.6-6. WMEC-SES Ride Quality - 35 Knots - Sea State 3 - Cushionborne with Ride Control

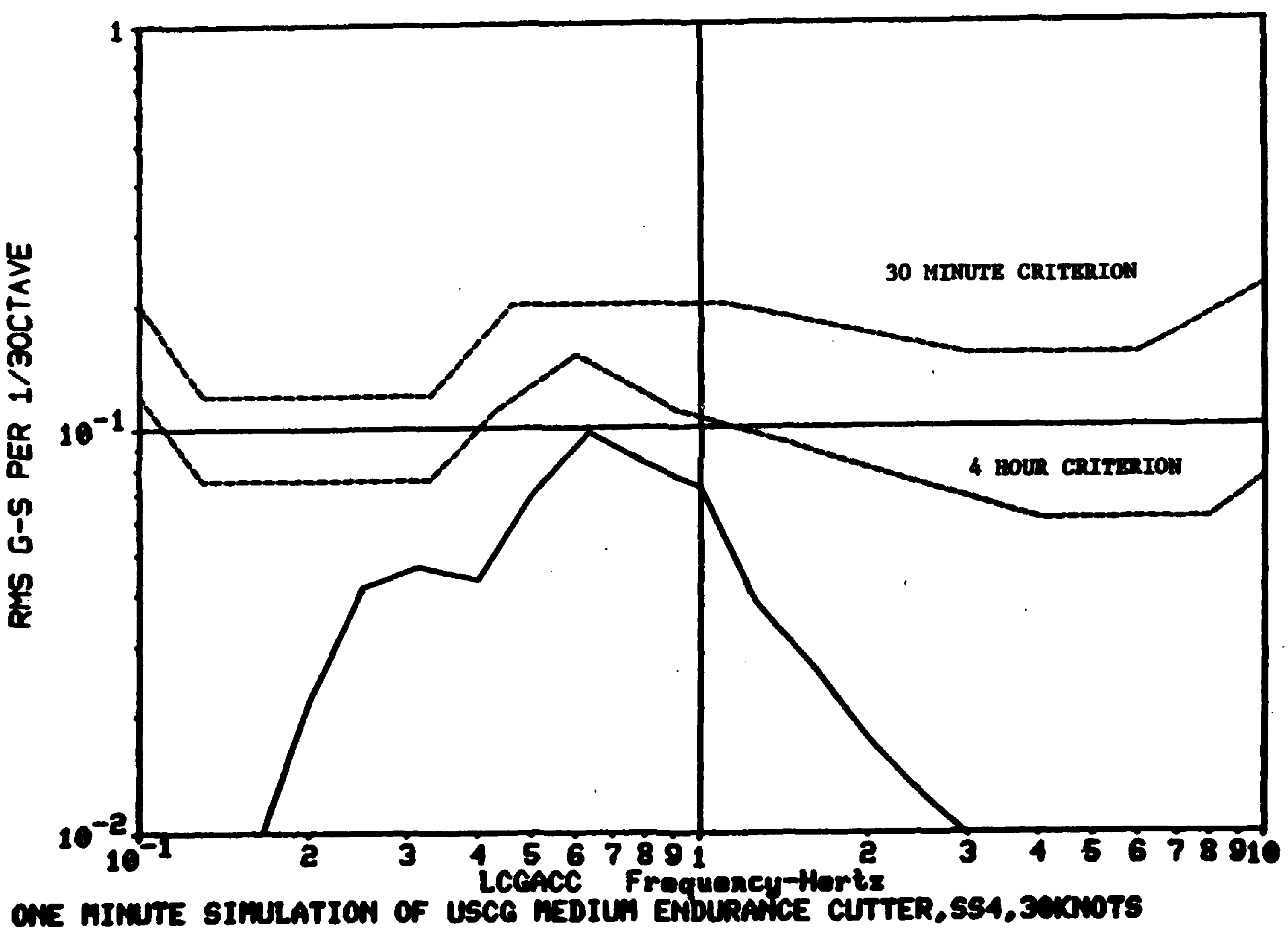


Figure 2.6-7. WMEC-SES Ride Quality - 30 Knots - Sea State 4 - Cushionborne with Ride Control

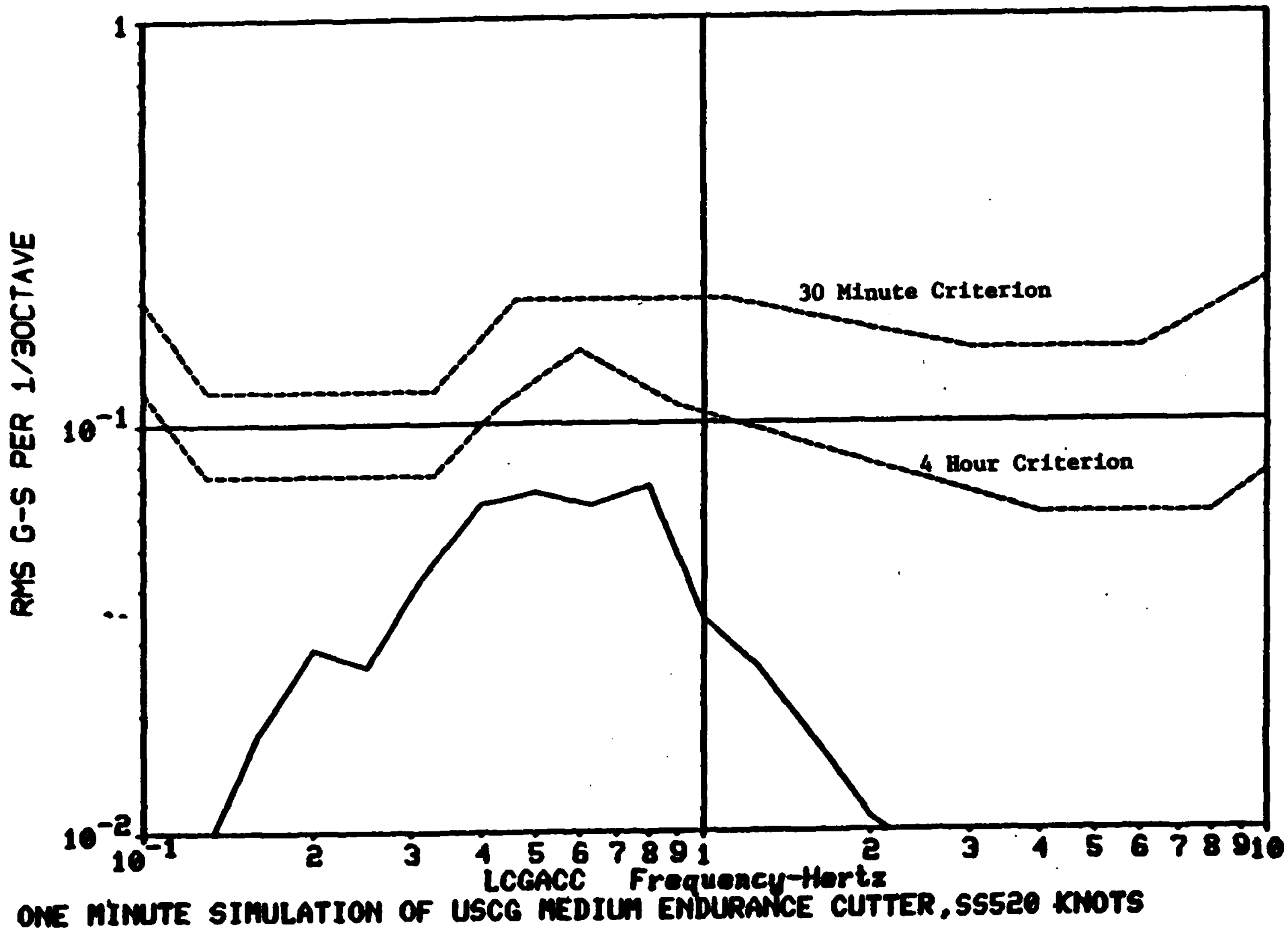


Figure 2.6-8. WMEC-SES Ride Quality - 20 Knots - Sea State 5 - Cushionborne with Ride Control

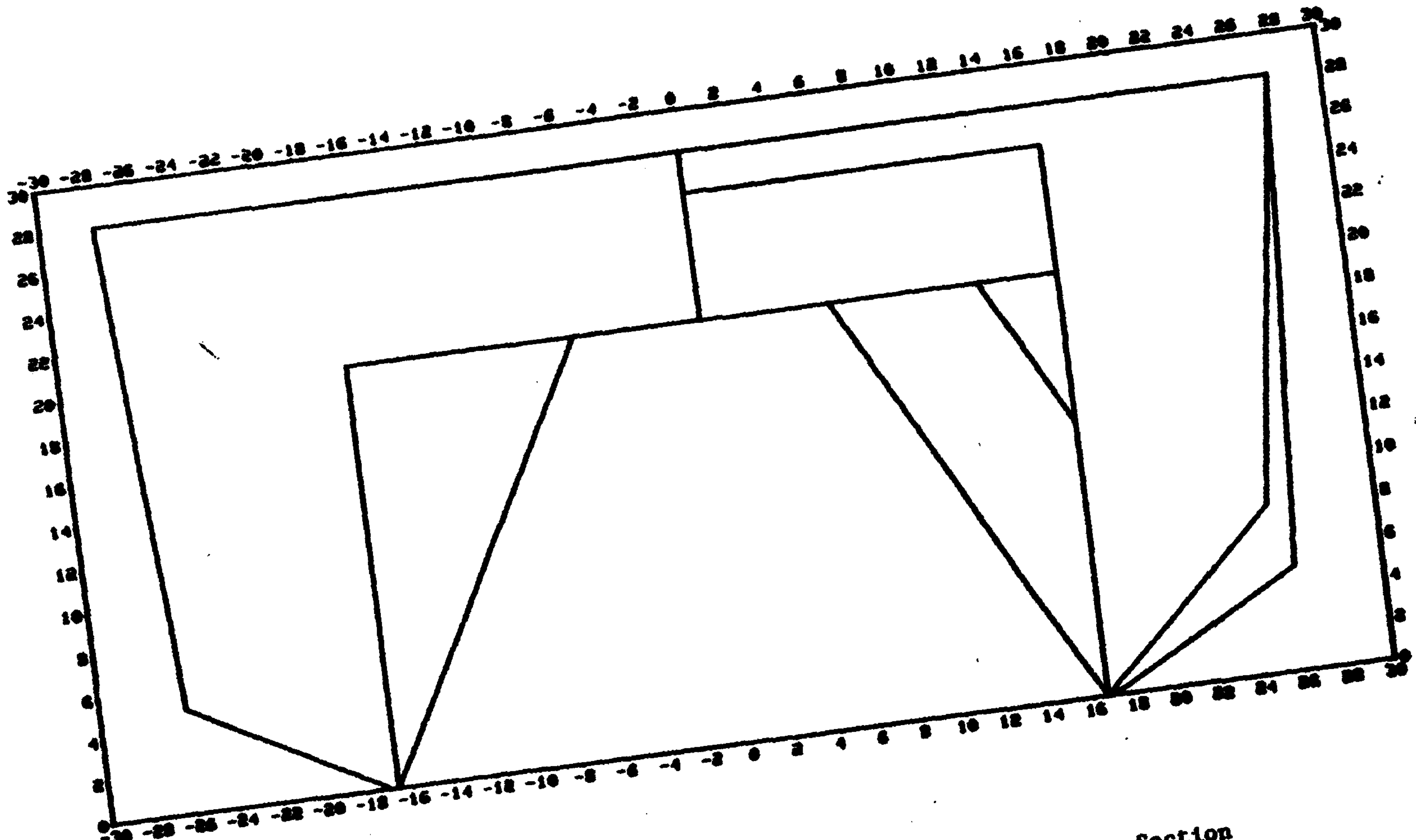


Figure 2.6-9. WMEC-SES Hydrostatic Analysis - Transverse Section

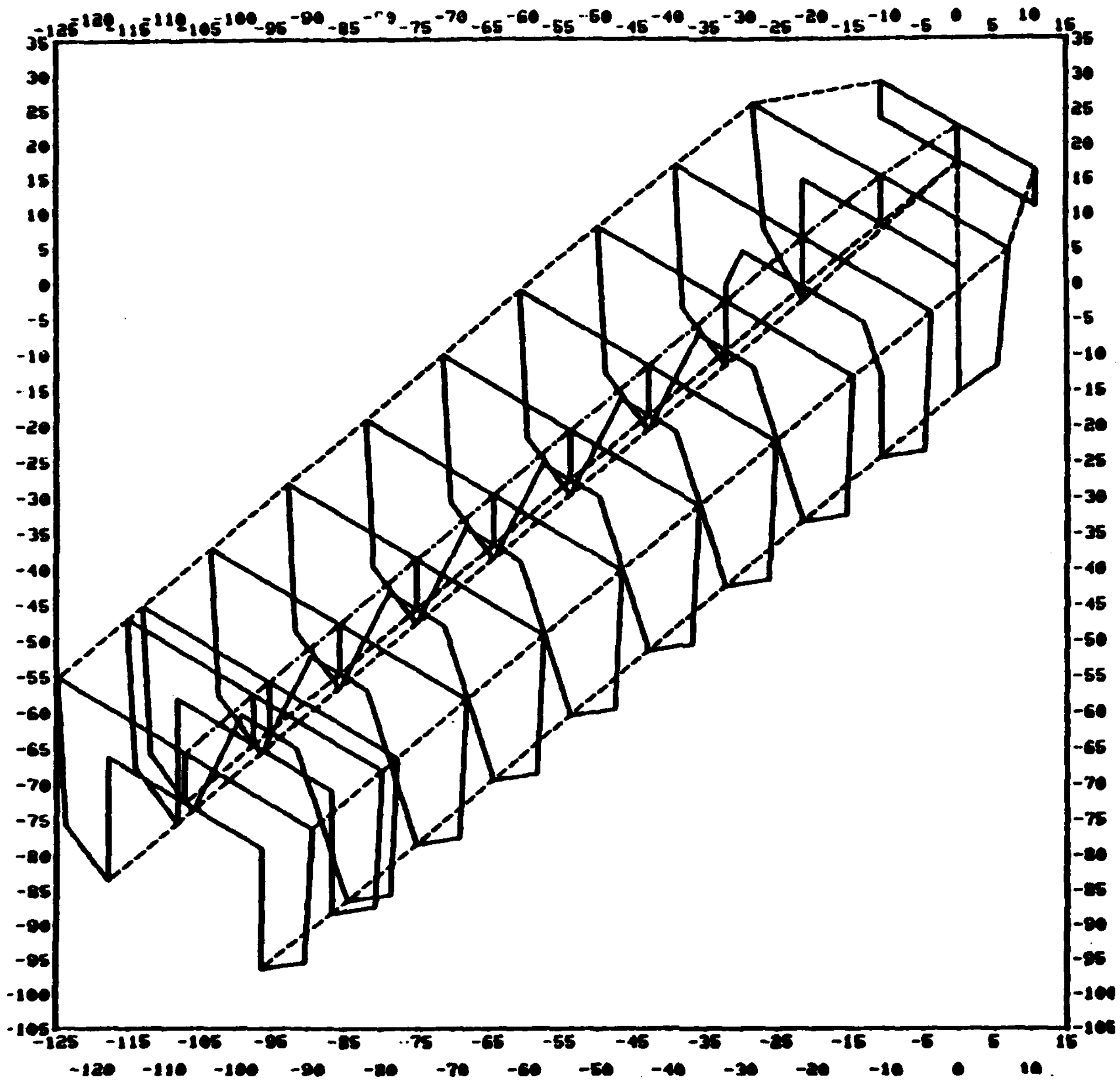


Figure 2.6-10. WMEC-SES Hydrostatic Analysis - Hull Geometry

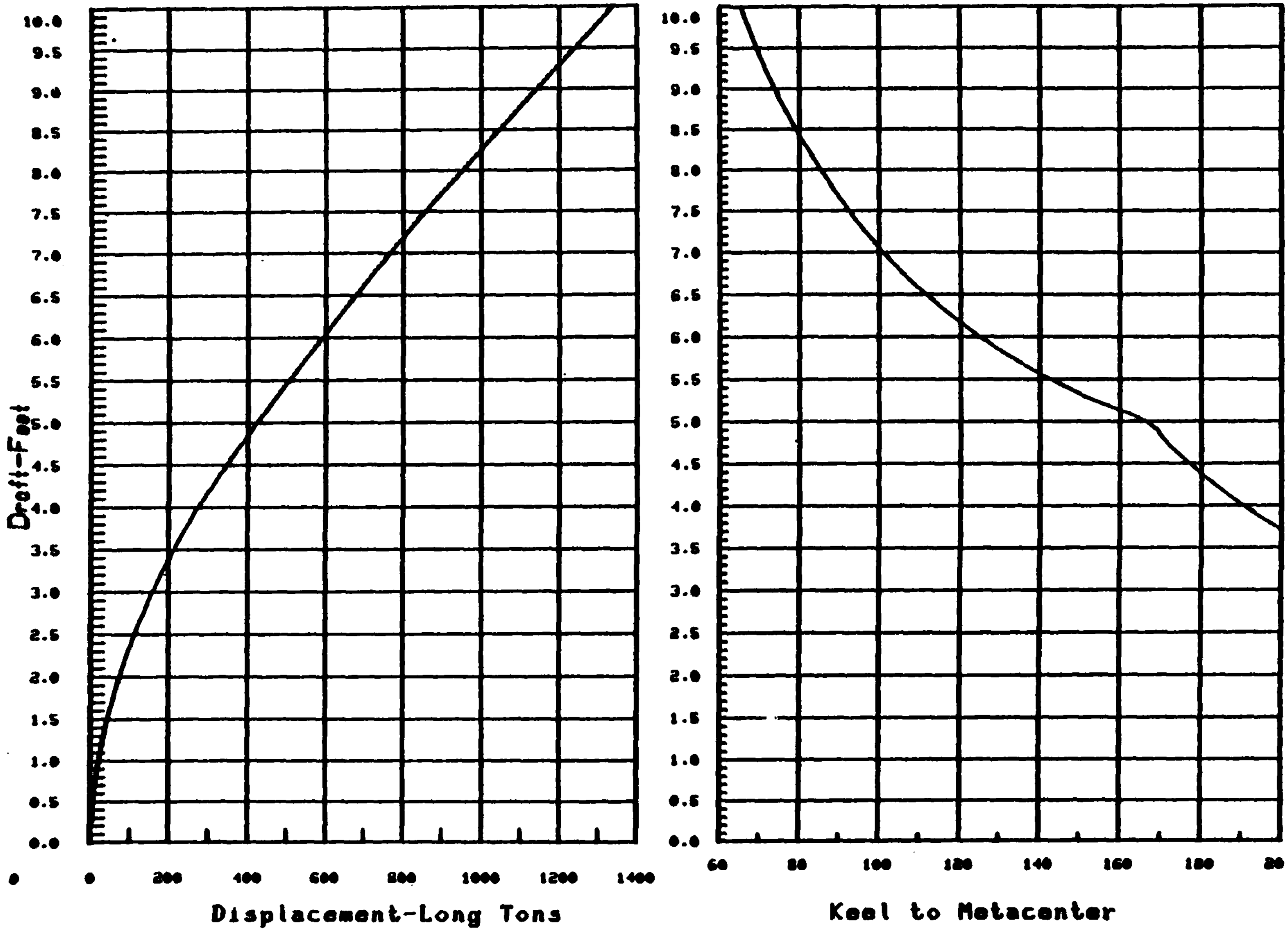


Figure 2.6-11. WMEC-SES Displacement, Draft, and Transverse Metacenter

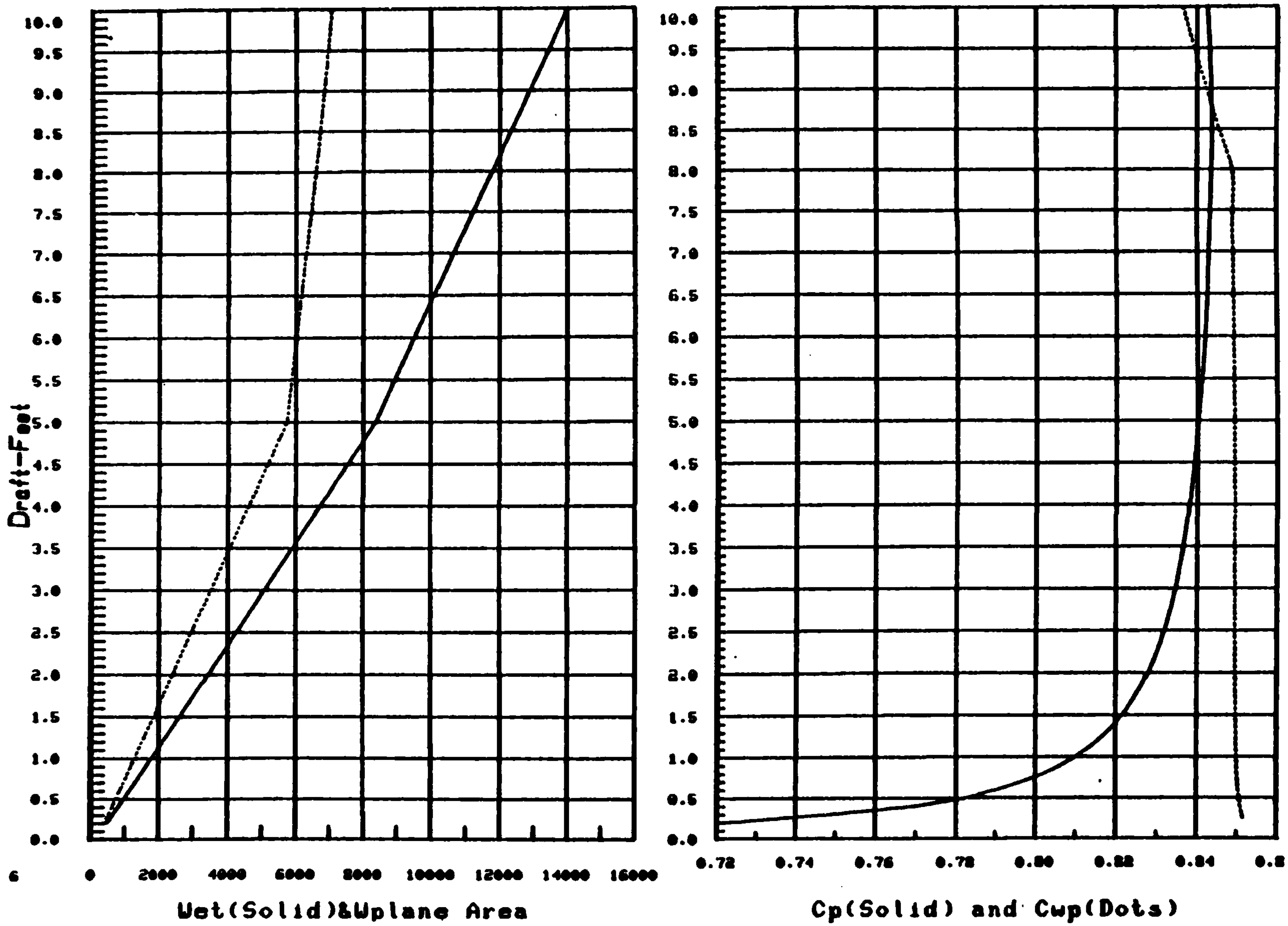


Figure 2.6-12. WMEC-SES Waterplane Area, Prismatic Coefficient and Waterplane Area Coefficient

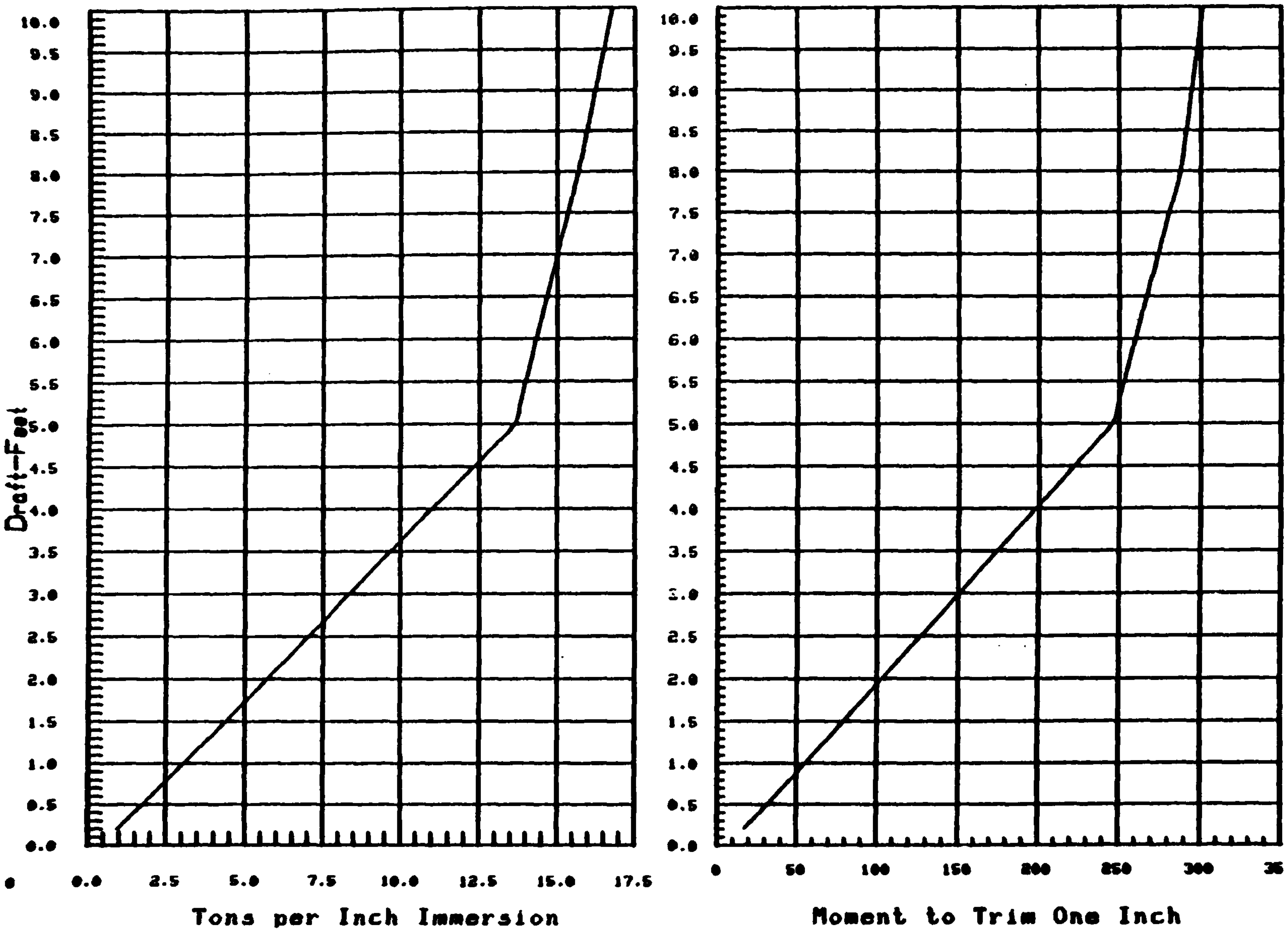


Figure 2.6-13. WMEC-SES Tons Per Inch Immersion and Moment to Change Trim One Inch

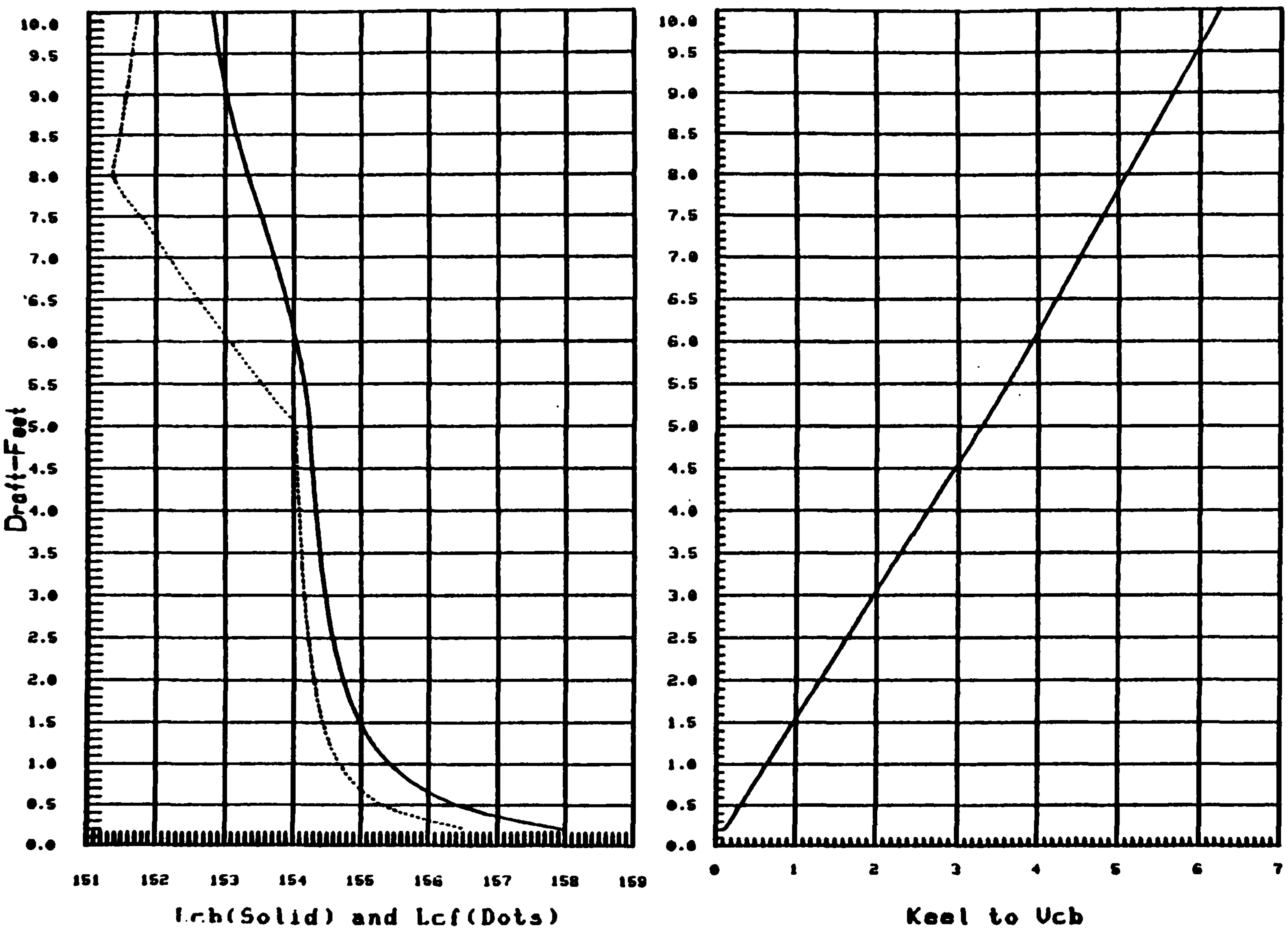


Figure 2.6-14. WMEC-SES LCB, LCF and VCB

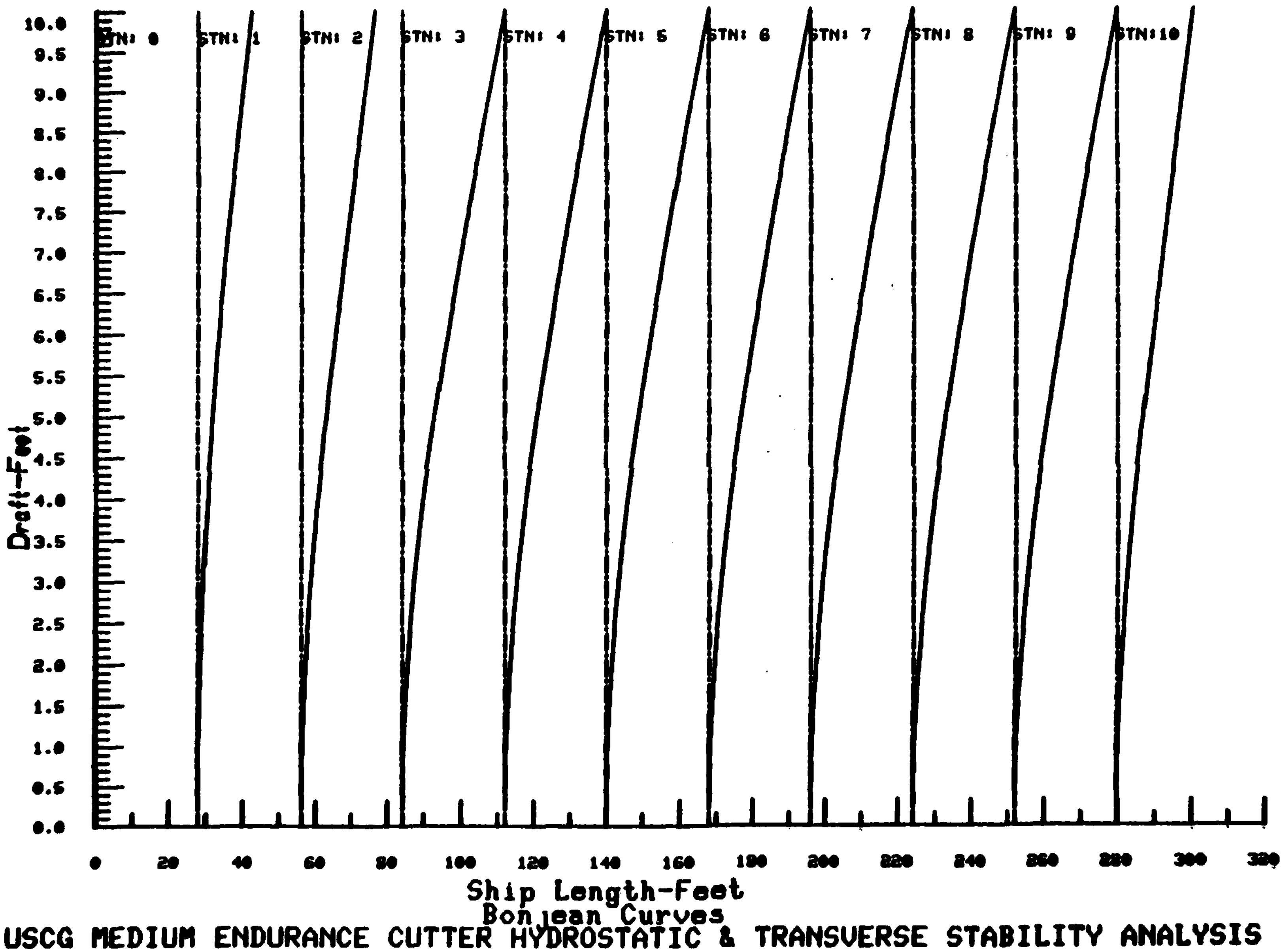
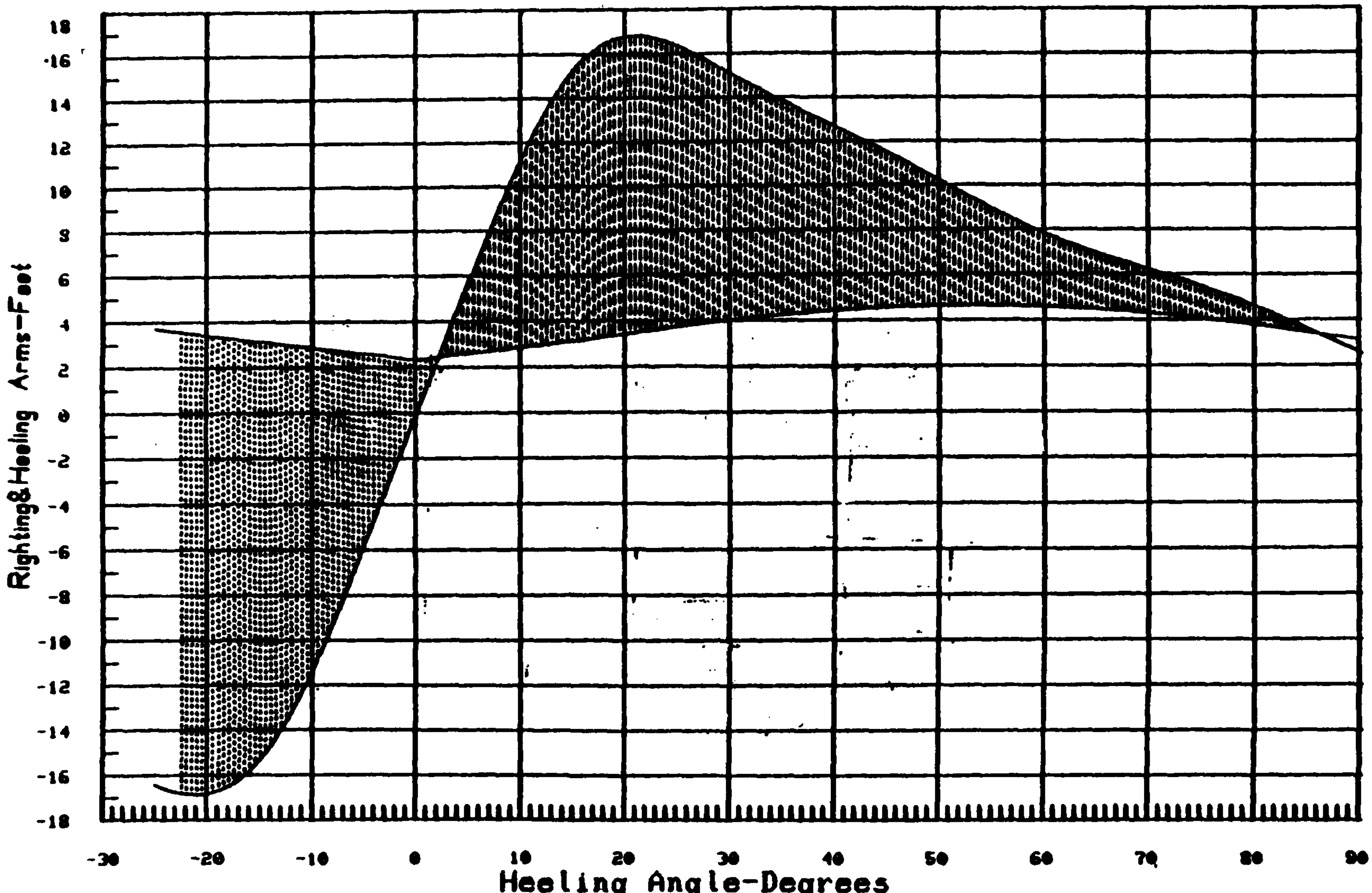


Figure 2.6-15. WMEC-SES Bonjean Curves



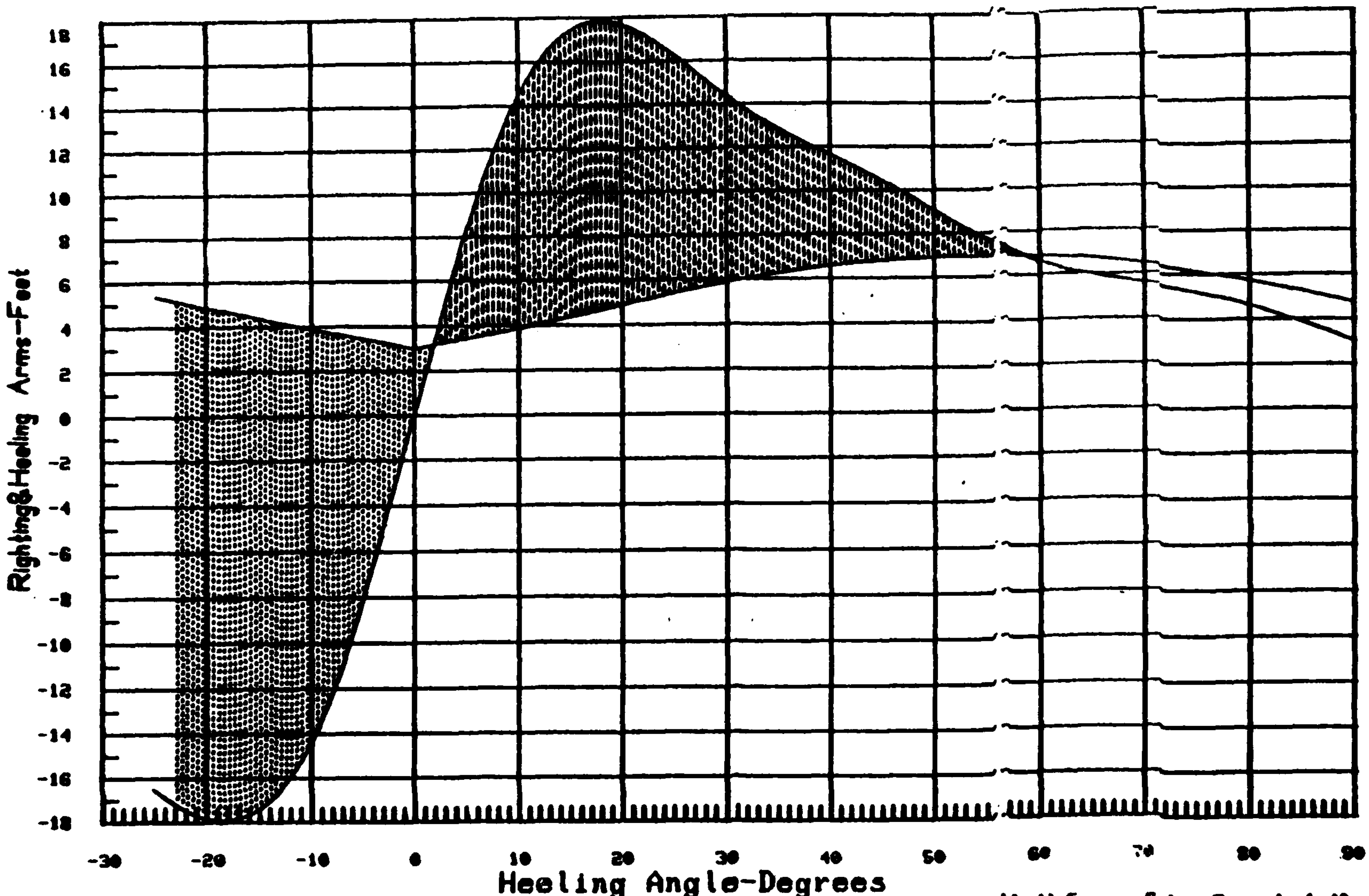
U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.40

Hydrostatic Properties for Ship in Intact Condition — Rolling Angle-25 Degrees — A1/A2- 1.64

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
1030.0	280.0	55.0	8.4	27.3	0.0	14.0	153.2	289.5	15.9	0.84	0.85	66.1	100.

Transverse Stabilitu-Beam Wind Combined with Rolling

Figure 2.6-16. WMEC-SES Intact Stability Wind Heel Full Load Condition



U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.40

Hydrostatic Properties for Ship in Intact Condition — Rolling Angle-25 Degrees — A1/A2= 0.98

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MT1	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
700.0	280.0	55.0	6.6	27.3	0.0	14.0	153.2	267.7	14.7	0.84	0.86	94.6	100.

Transverse Stability-Beam Wind Combined with Rolling

USCG MEDIUM ENDURANCE CUTTER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 2.6-17. WMEC-SES Intact Stability Wind Heel Burned Out Condition

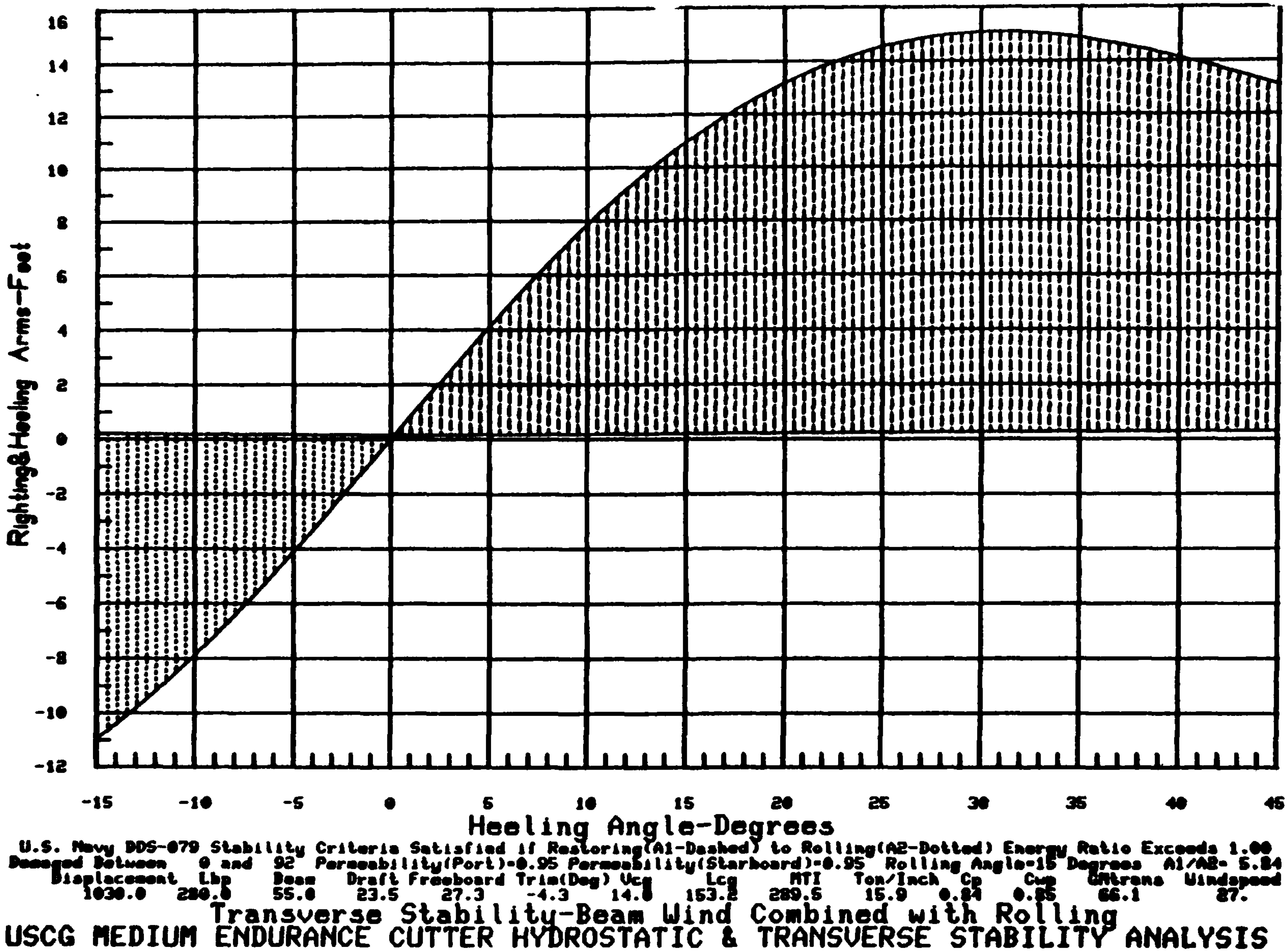


Figure 2.6-18. WMEC-SES Damage Stability Compartments 1 and 2, Shell-to-Shell Damage

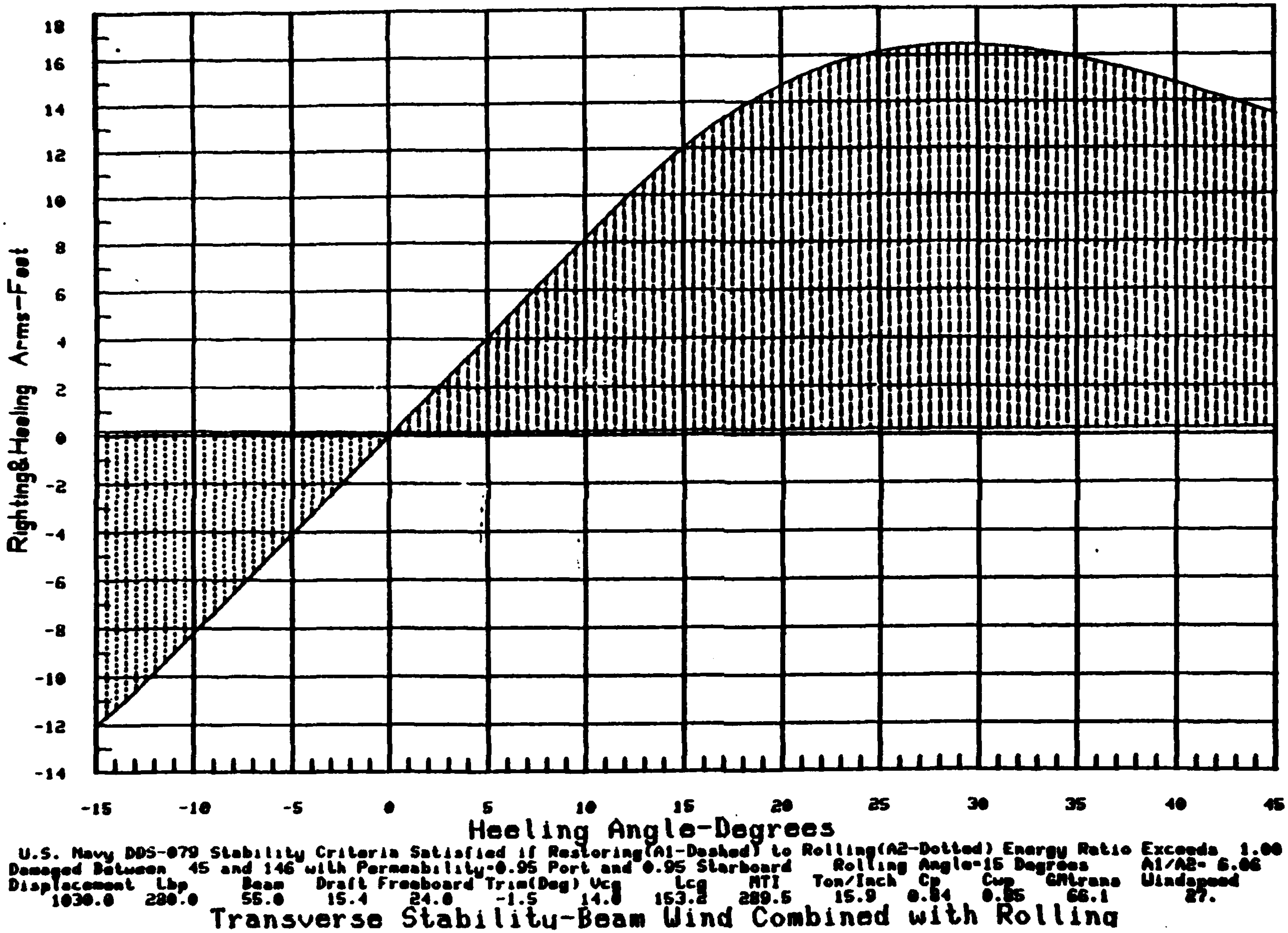


Figure 2.6-19. WMEC-SES Damage Stability Compartments 2 and 3, Shell-to-Shell Damage

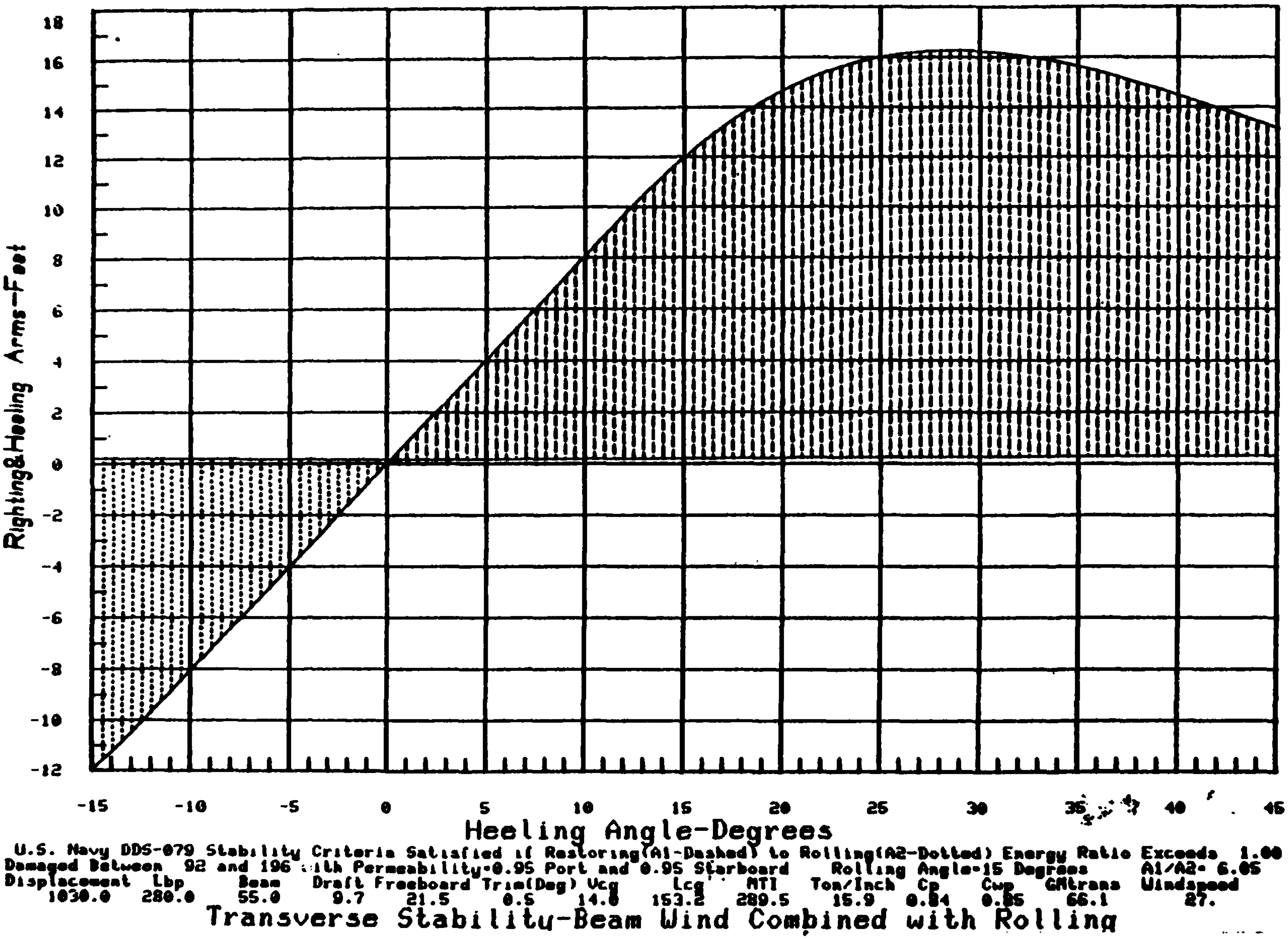


Figure 2.6-20. WMEC-SES Damage Stability Compartments 3 and 4, Shell-to-Shell Damage

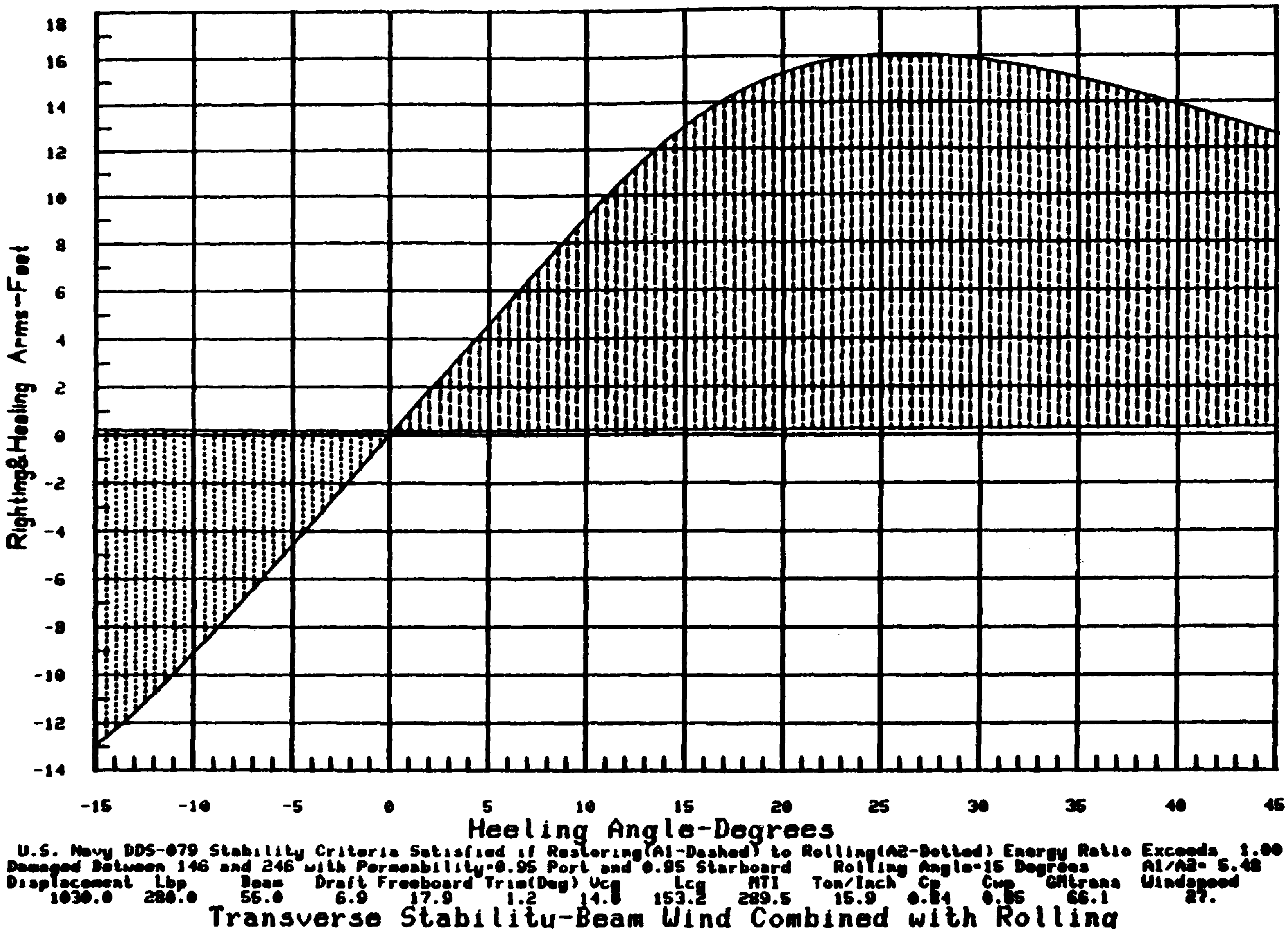


Figure 2.6-21. WMEC-SES Damage Stability Compartments 4 and 5, Shell-to-Shell Damage

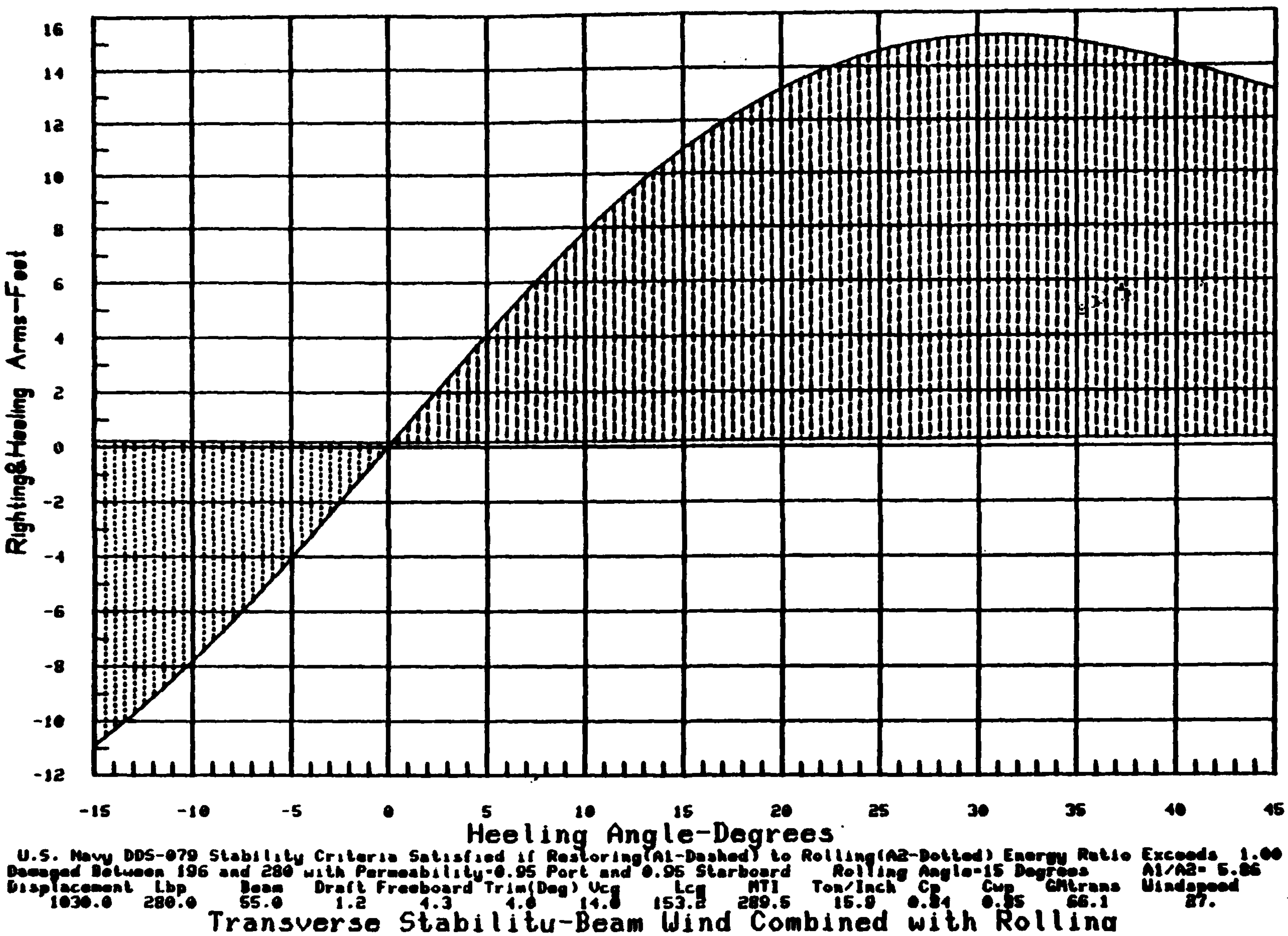


Figure 2.6-22. WMEC-SES Damage Stability Compartments 5 and 6, Shell-to-Shell Damage

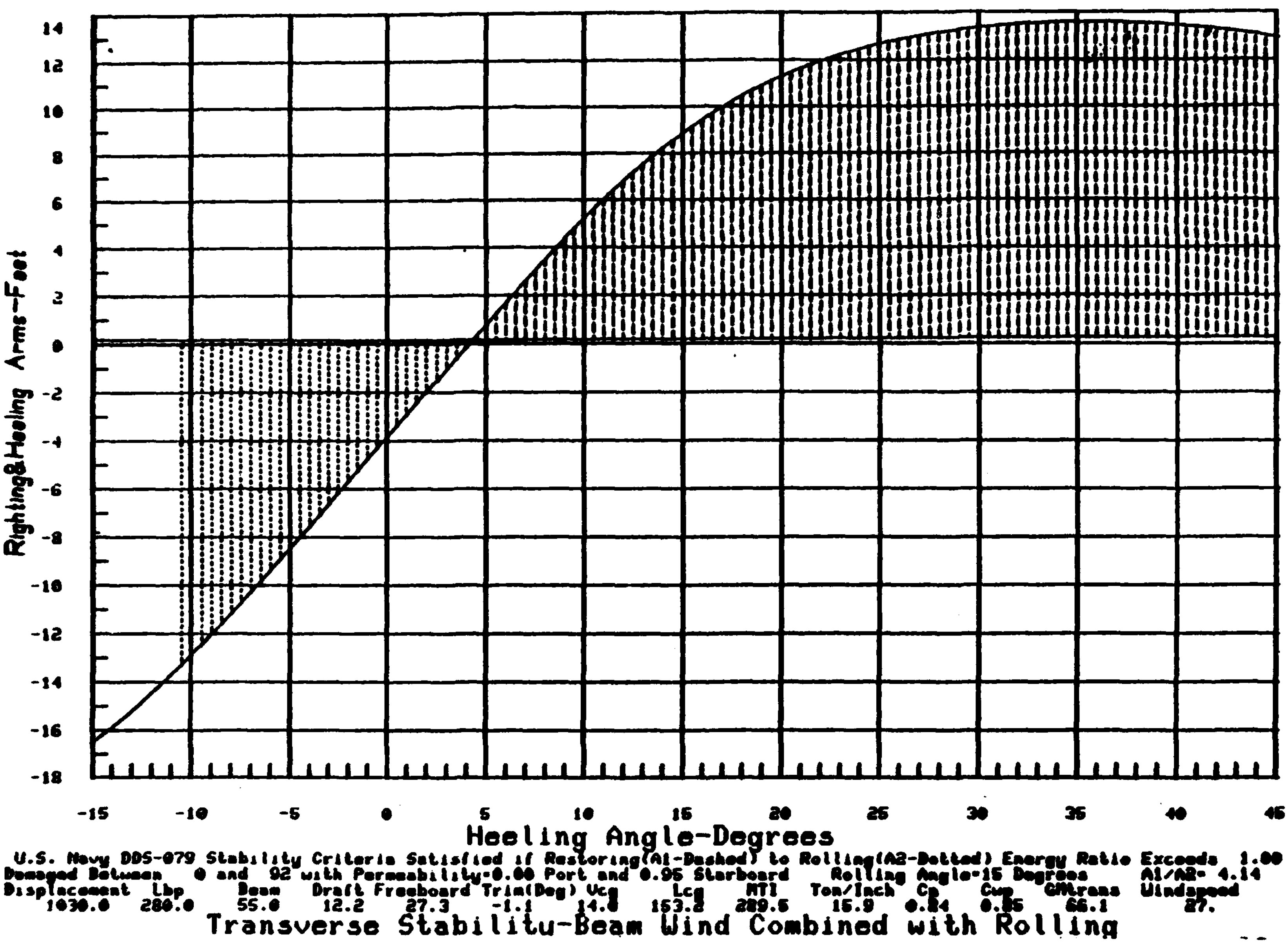


Figure 2.6-23. WMEC-SES Damage Stability Compartments 1 and 2, Damage to Centerline

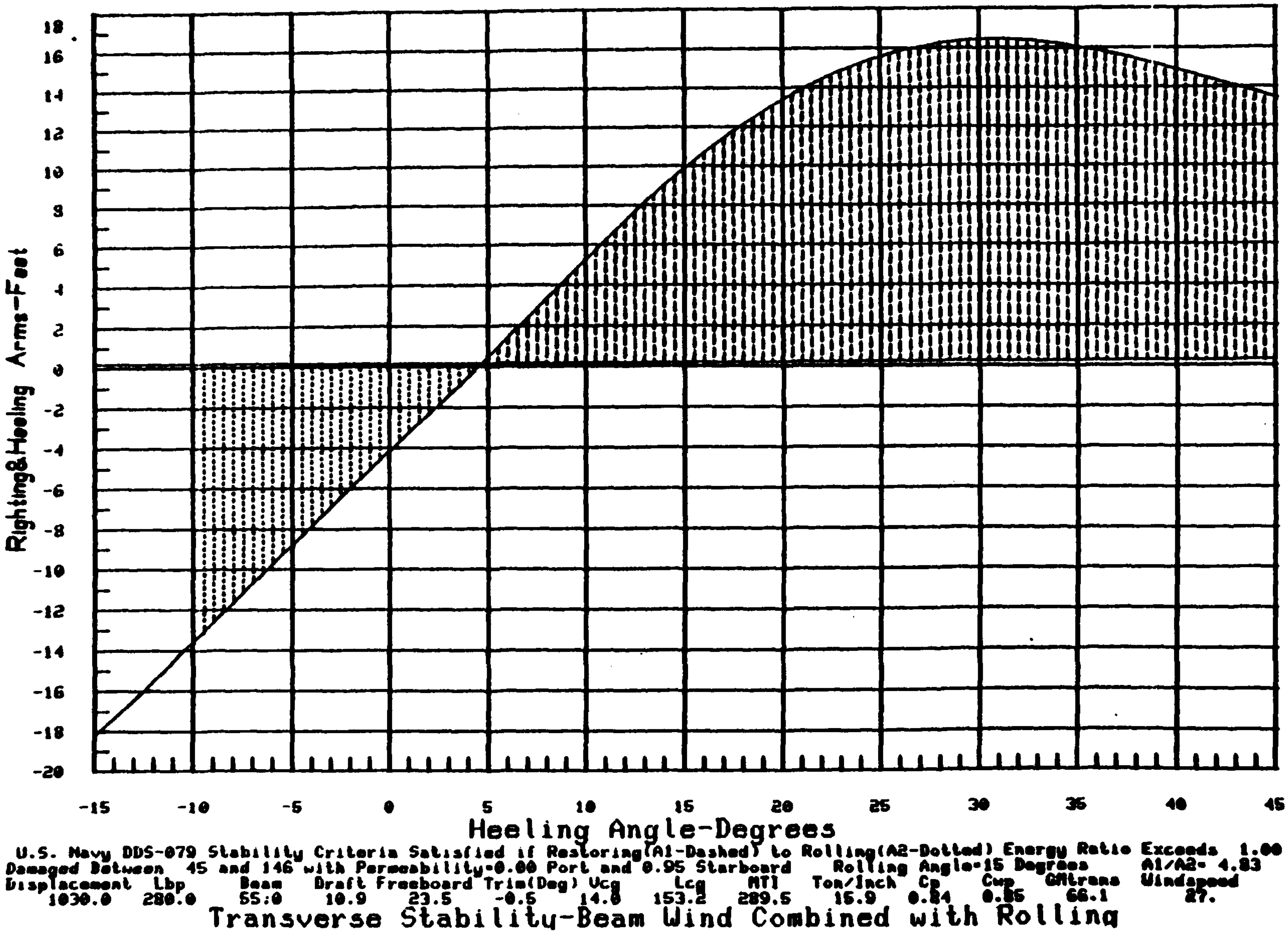


Figure 2.6-24. WMEC-SES Damage Stability Compartments 2 and 3, Damage to Centerline

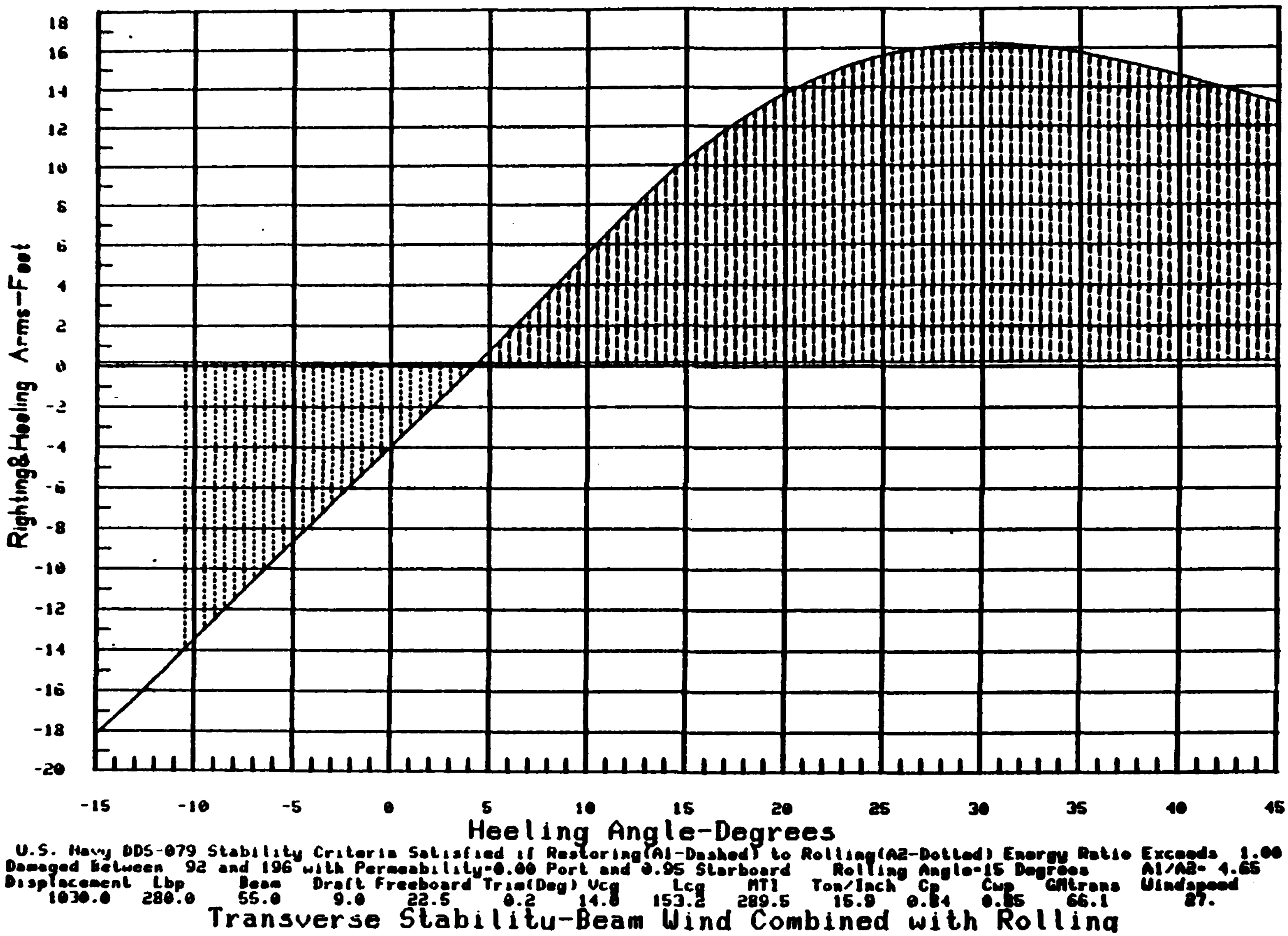


Figure 2.6-25. WMEC-SES Damage Stability Compartments 3 and 4, Damage to Centerline

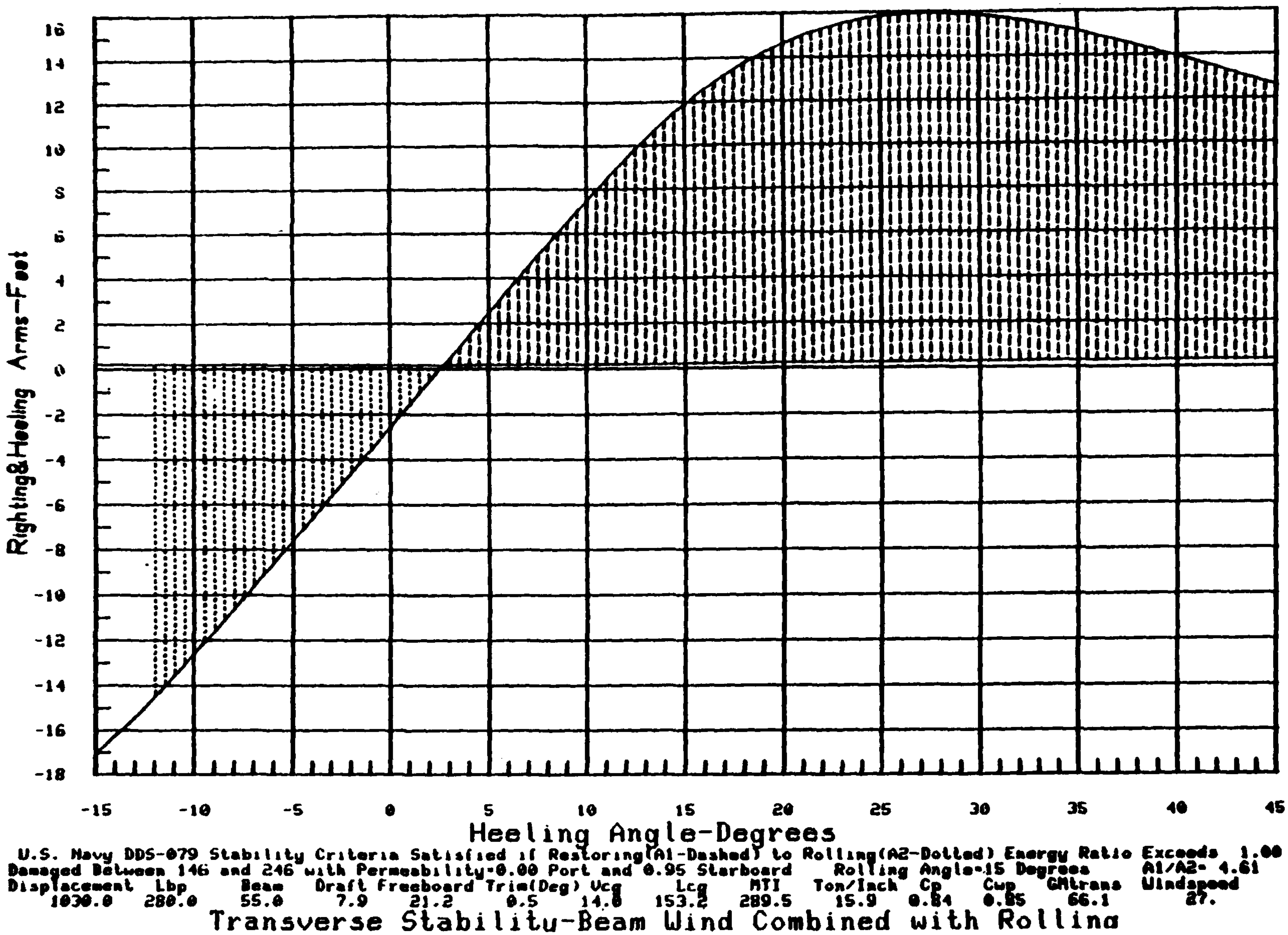


Figure 2.6-26. WMEC-SES Damage Stability Compartments 4 and 5, Damage to Centerline

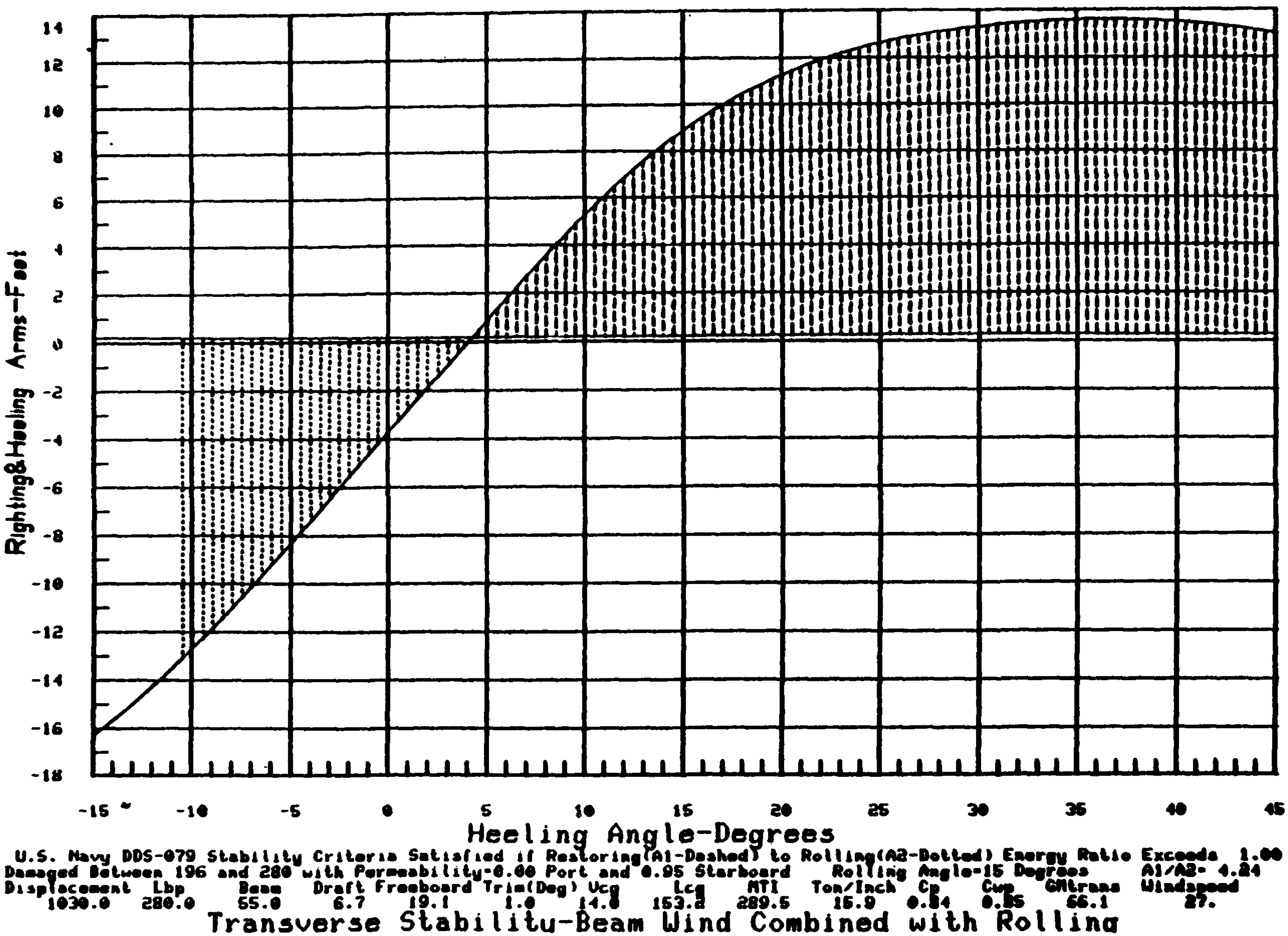


Figure 2.6-27. WMEC-SES Damage Stability Compartments 5 and 6, Damage to Centerline

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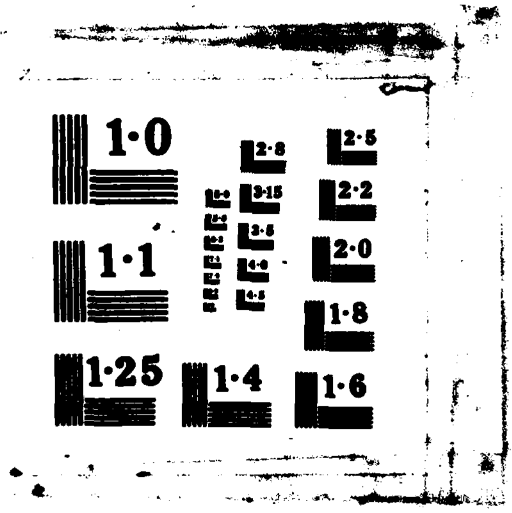
1·0
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APPENDIX 3

DESIGN DESCRIPTION - WLB-SES

1. INTRODUCTION

This appendix provides a description of a surface effect ship design concept developed to meet the requirements of the existing USCG-WLB craft. The design concept is described in terms of layout drawings, tables, and text.

2. PRINCIPAL CHARACTERISTICS

The principal characteristics of the WLB-SES are summarized in Table 3.2-1.

3. MISSION REQUIREMENTS

The mission requirements are summarized in Table 3.3-1.

4. SHIP CONFIGURATION

The WLB-SES outboard profile and hull geometry are shown in Figures 3.4-1 and 3.4-2 respectively. The principal features of the general arrangement and major subsystems are discussed in the following paragraphs.

4.1 GENERAL ARRANGEMENT -- The general arrangement is shown in Figure 3.4-3. As shown in Figure 3.4-3, the general arrangement features:

a. A large, clear deck area located close to the vessel mid-length to facilitate buoy handling operations.

Table 3.2-1. WLB-SES - Principal Characteristics

Length Overall	220 Ft - 0 In
Length Cushion	196 Ft - 0 In
Breadth Overall	50 Ft - 0 In
Breadth Cushion	31 Ft - 0 In
Depth Main Deck	24 Ft - 6 In
Depth Cushion	16 Ft - 0 In
Full Load Displacement	800.6 Long Tons
Cruising Speed (Maximum Continuous Power and SS 0)	20 Knots
Propulsion Machinery	Two SACM 16V195RVR Diesel Engines
Propellers	Two Propellers
Lift Engines	Two MTU 8V331TC92 Diesel Engines
Lift Fans	Four Mixed Flow
Accommodations:	
Officers	4
CPO's	2
Enlisted Personnel	42
Total	48

Table 3.3-1. WLB Design Requirements

A. Missions:

SRA - Short Range Aids To Navigation

SAR - Search and Rescue
ELT - Enforcement of Laws & Treaties
MER - Marine Environmental Response

B. Mission Equipment:

1600 FT^2 of deck space capable of supporting 50 Ltons
Hold capacity of 4,300 FT^3
(2) 6M RHI w/SPD (6.6 Ltons-(2)-19'x8'x4')
Storage of 10,000 gal. fuel and 15,000 gal. water for logistics
No Major weapons
20 Ltons crane capability
Stores (2.0 Ltons)
Crew (11.6 Ltons)
C^3 and Navigation (9.4 Ltons)

C. Speed vs. Sea State:

20 kts in Calm Water
18 kts in SS2
15 kts in SS3

D. Endurance:

10 - 14 days

1000-4000 NM with 10% reserve fuel

E. N/A - to be governed by (D.)

F. Operating Environment:

Occasional transit of ice burdened waters in Great Lakes and 1st and 3rd CG Districts. Extended deployment and severe weather in the 14th and 17th Coast Guard Districts.

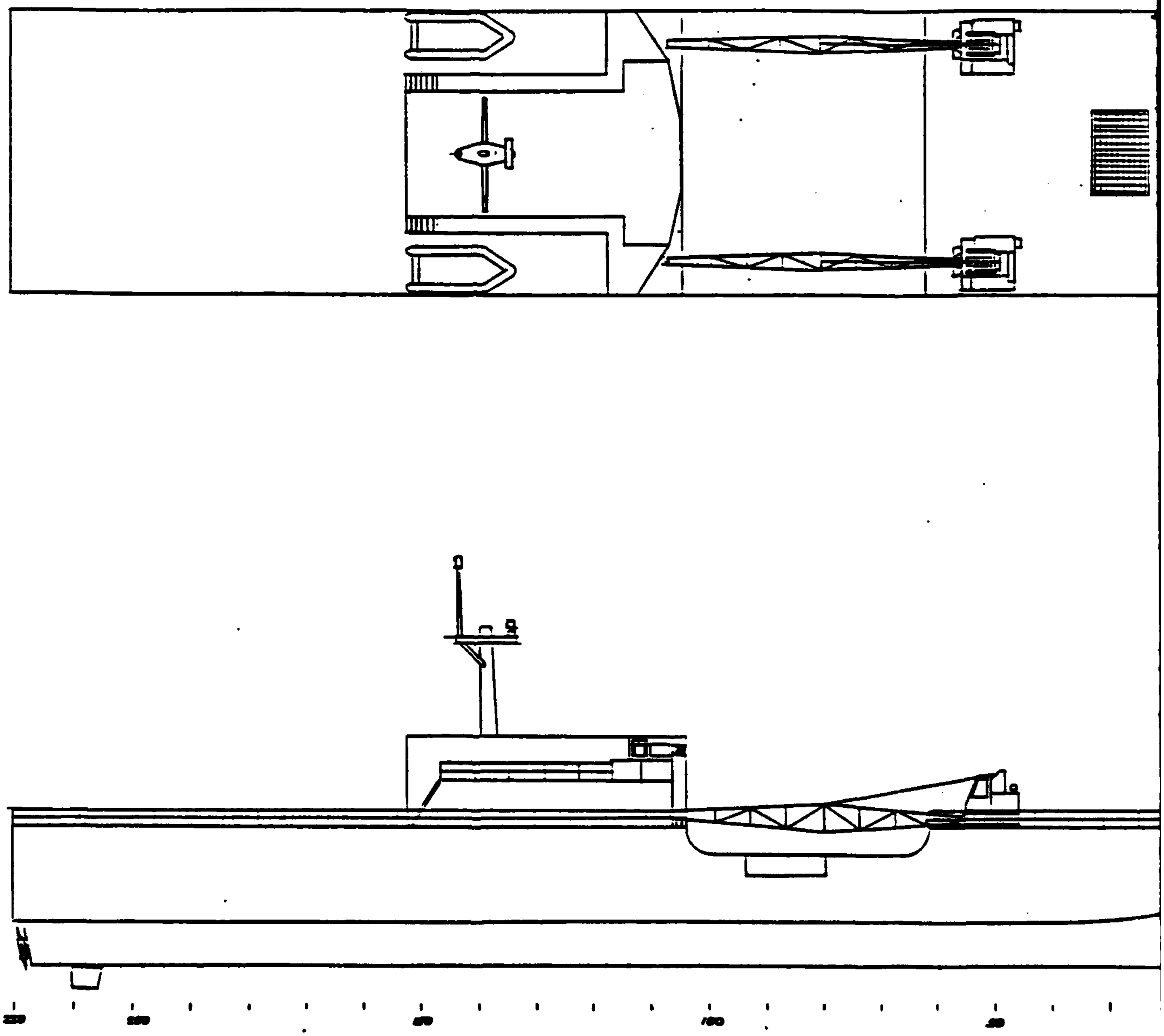
G. Complement:

48 Permanent Crew

4-Officers
2-CPOs
42-Enlisted

H. Other Design Features:

1. Minimum freeboard at buoy deck (less than 5')
2. 360 deg vision for OOD
3. Remote steering and engine control station
4. Largest buoy 9x38 (LGR)=19,400 #'s + chain + (Weight of water if flooded)
5. Good low speed maneuverability
6. 14 Ft maximum draft
7. 20-Yr hull lift
8. Steel construction
9. Survivability in SS6
10. Operate through SS4



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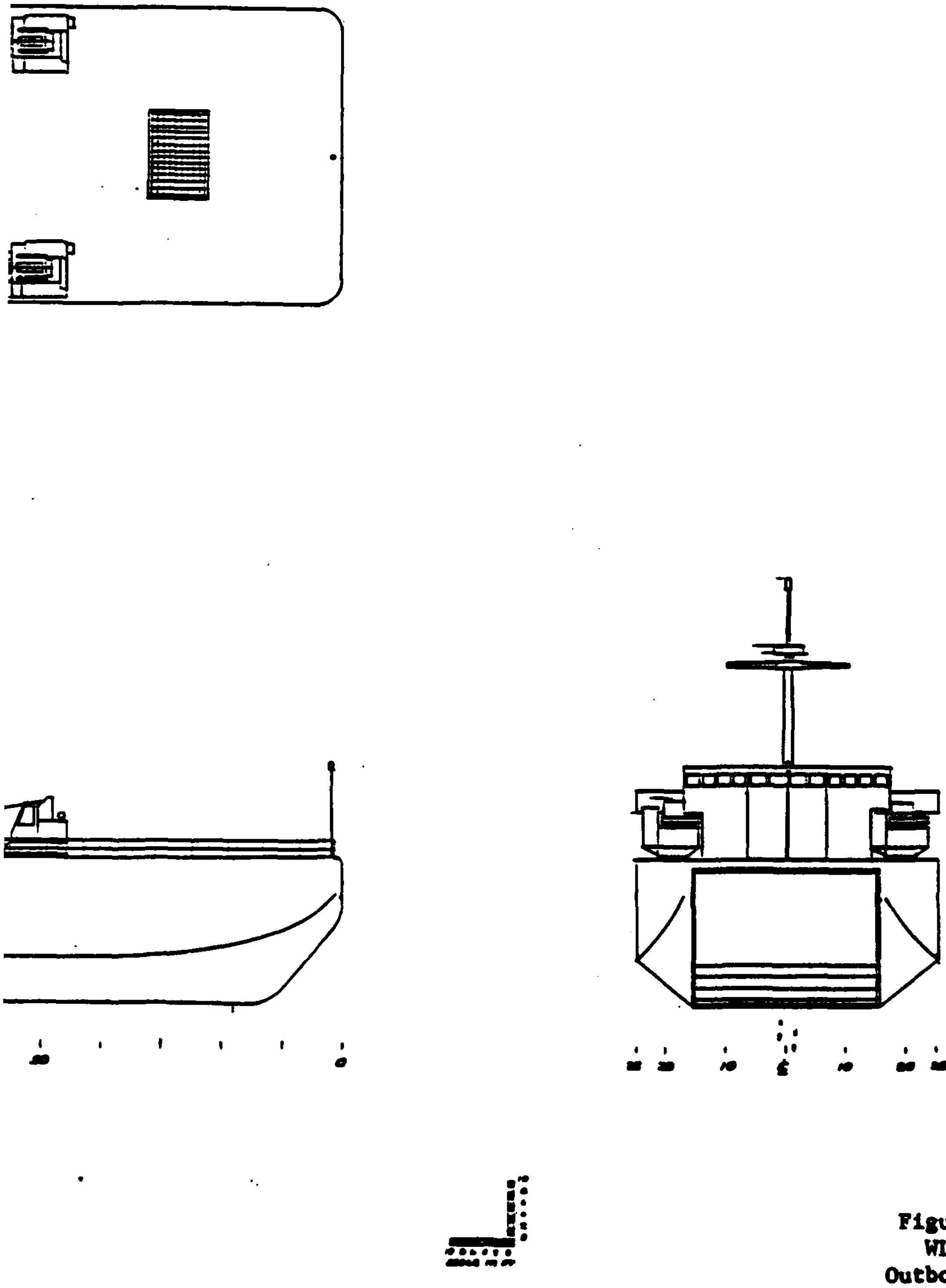
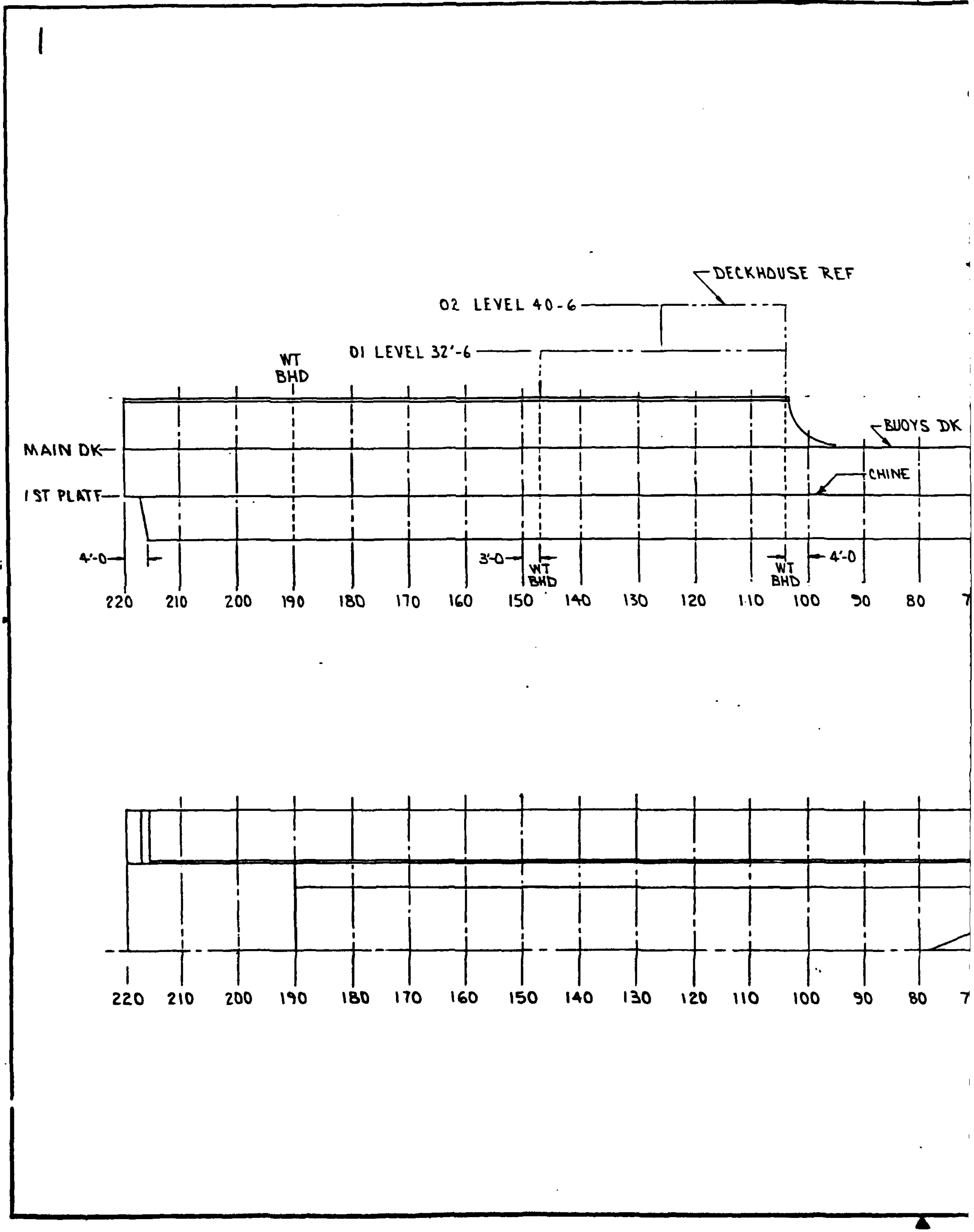


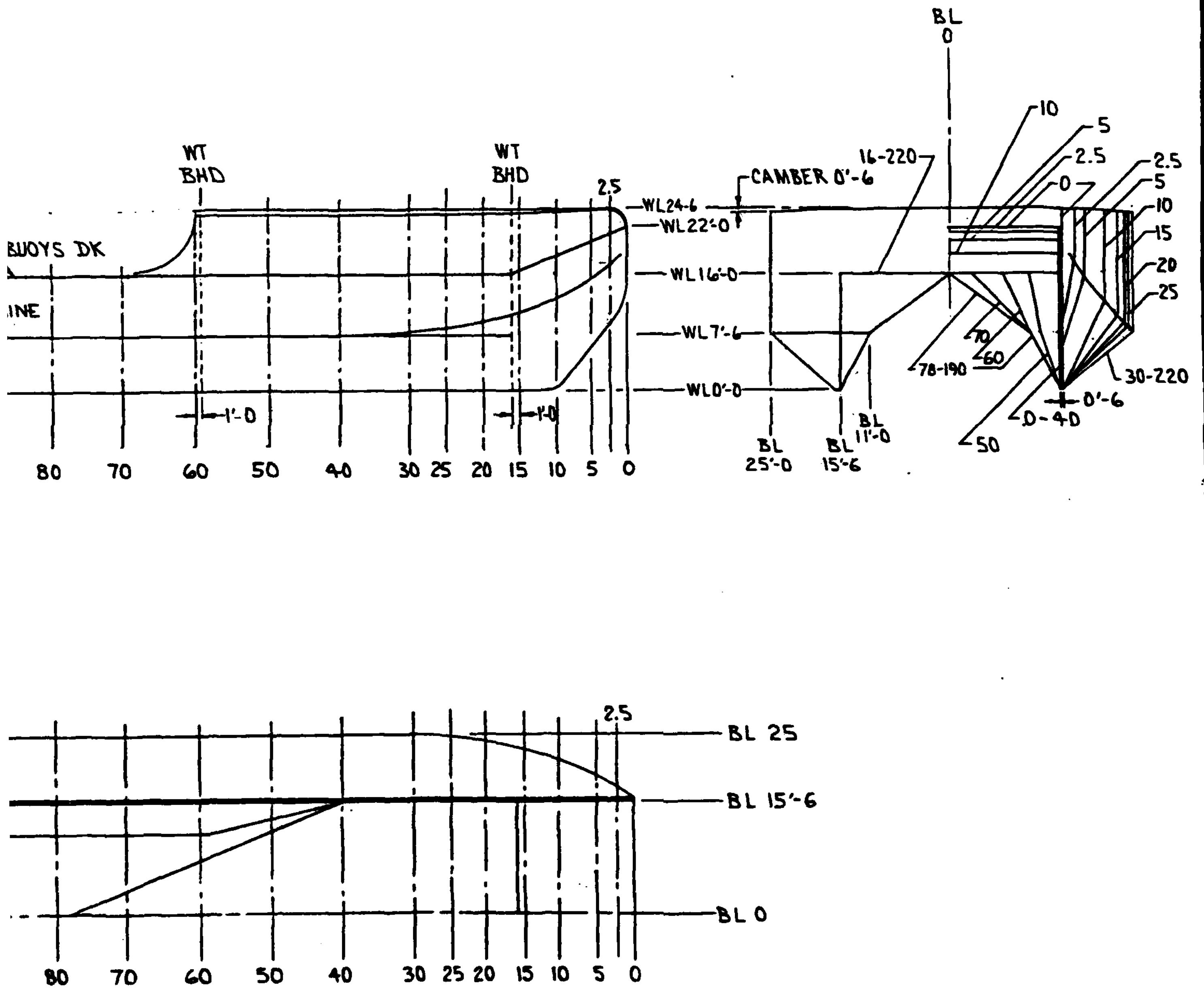
Figure 3.4-1
WLB-SES
Outboard Profile



DECKHOUSE REF
02 LEVEL 40-6
01 LEVEL 32'-6
WT BHD
BUOYS DK
MAIN DK
CHINE
1ST PLATF
4'-0
3'-0
WT BHD
WT BHD
4'-0
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80

PRINCIPAL PARTICULARS

LENGTH OVERALL	220'-0
BEAM OVERALL	50'-0
CUSHION LENGTH	196'-0
CUSHION BEAM	31'-0
CUSHION DEPTH	16'-0
DEPTH TO MAIN DECK	24'-6
DESIGN DISPLACEMENT	800 L TONS
DRAFT HULLBORNE	8'-5



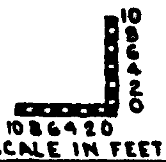
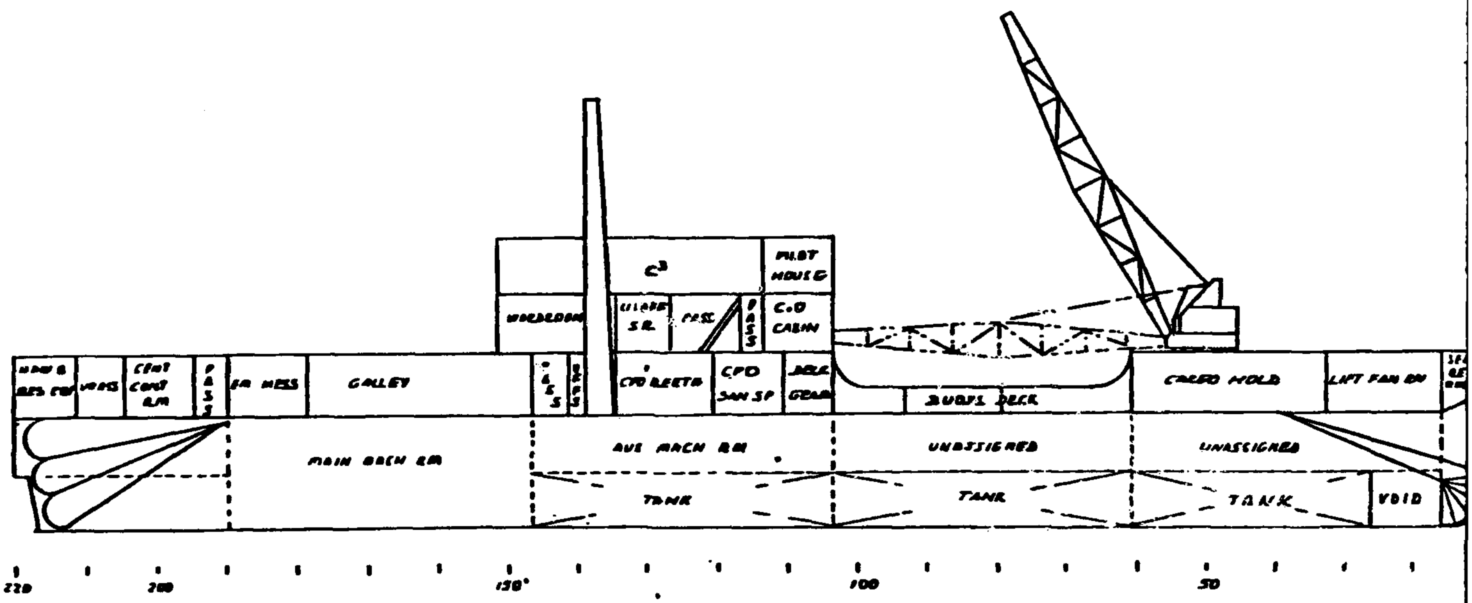
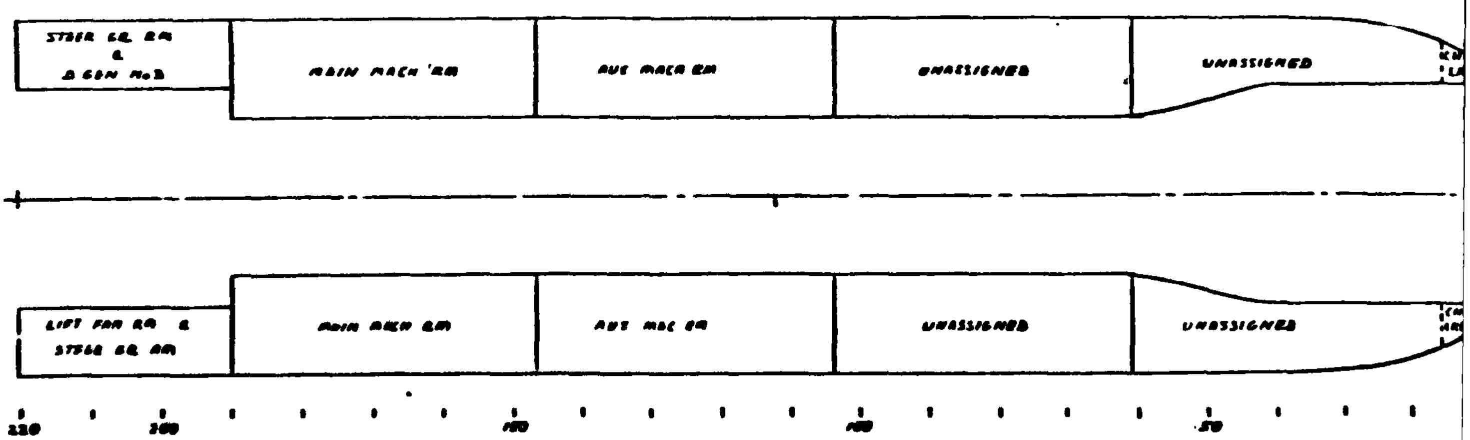


Figure 3.4-2. WLB-SES Hull Lines



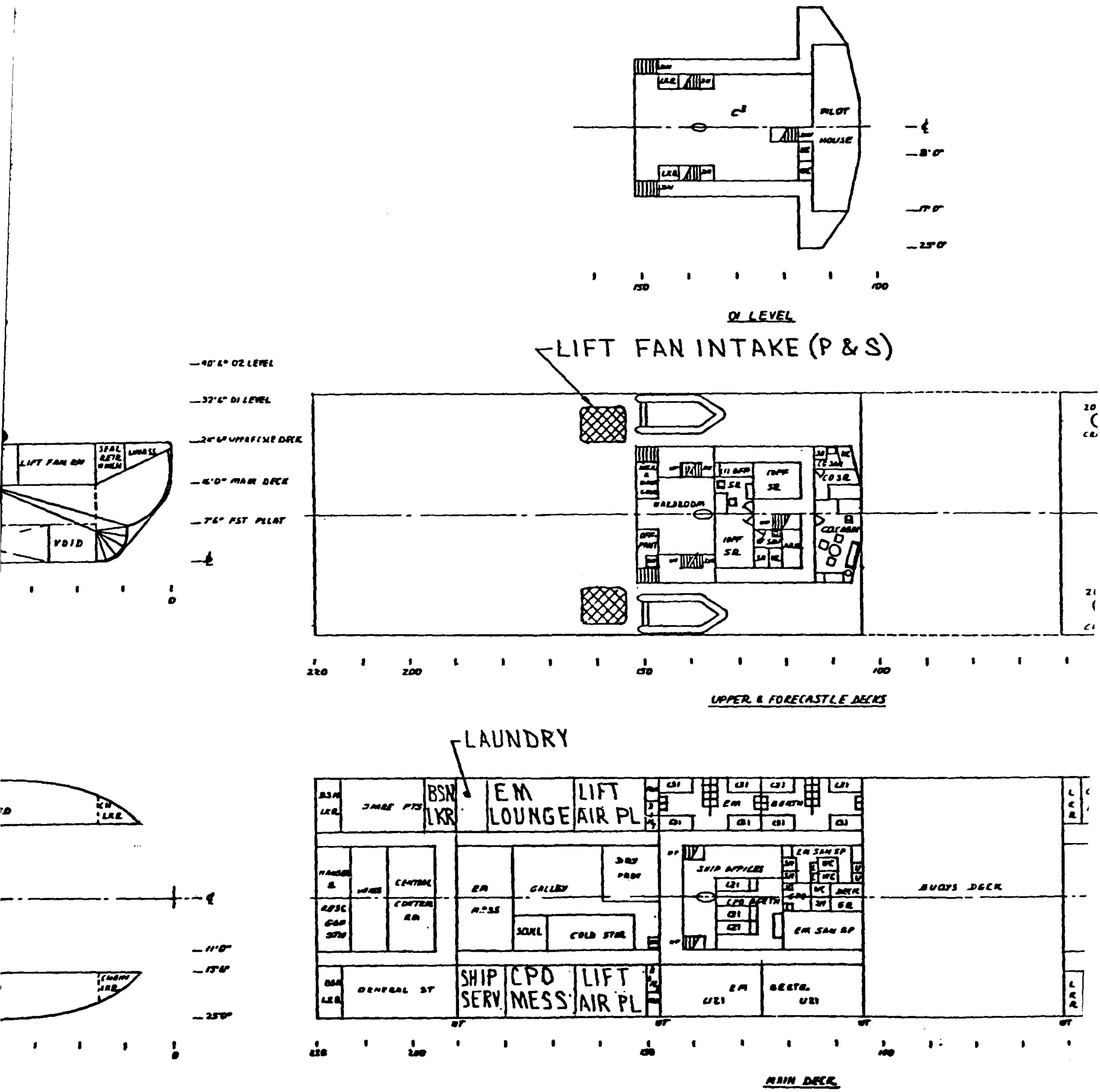
INBOARD PROFILE (℄)



FIRST PLATFORM

1

2


PILOT
HOUSE
01 LEVEL
LIFT FAN INTAKE (P & S)
LIFT FAN RM
VOID
UPPER & FORECASTLE DECKS
LAUNDRY
BSN LKR
EM LOUNGE
LIFT AIR PL
SHIP SERV
CPO MESS
LIFT AIR PL
GALLEY
COLD STR
SHIP OFFICES
EM SAN SP
EM BERTH
BUOYS DECK
MAIN DECK

Figure

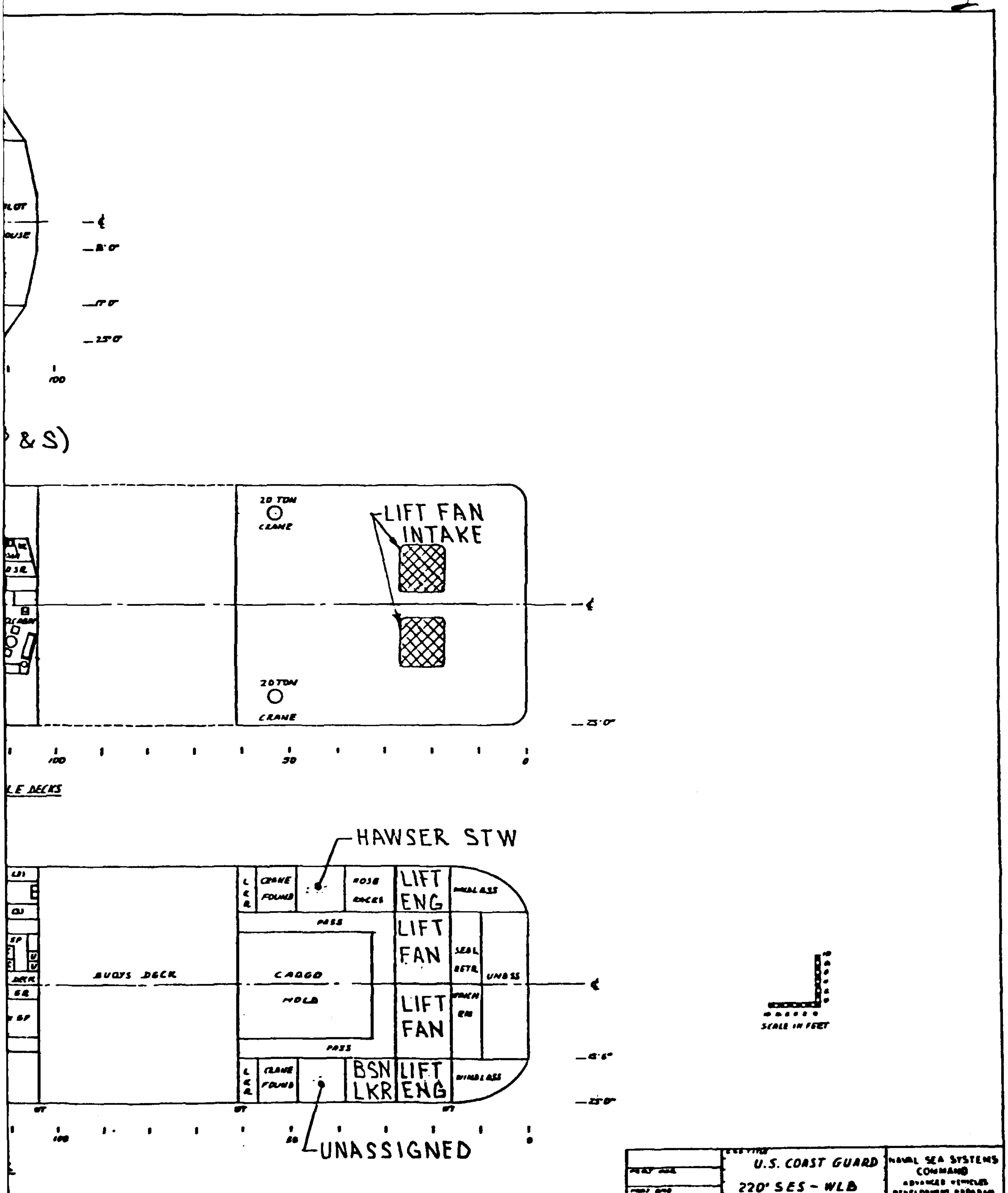


Figure 3.4-3. WLB-SES General Arrangement

b. Two 20-ton cranes located forward of the buoy handling deck with one crane located on each side of the ship.

Habitability spaces such as CPO and enlisted personnel living spaces, ship offices, galley and the general control room are located on the Main Deck level aft of the buoy handling area. The Main Deck forward of the buoy handling area is primarily dedicated for cargo and miscellaneous stowages and the installation of the forward lift fan.

The Upper and Forecastle deck levels are located one level above the Main Deck. The officer's living spaces are located approximately amidships on the Upper Deck. The Pilot House is located on the 01 level immediately above the officer's living spaces.

Direct access between the officer's living space and the Pilot House is provided. The habitability space deck area allocations and other hull volume allocations are summarized in Table 3.4-1. For comparison, the habitability space allocations provided in the existing conventional 190-Ft. WLB ship are also shown in Table 3.4-1.

4.2 HULL STRUCTURE -- All primary hull structure is constructed of high strength low alloy steel. Platform decks and other non-primary structure is constructed from lightweight honeycomb panels designed to withstand local loading. The structural arrangement is shown in Figure 3.4-4. The structural design criteria and the shear and bending moment envelopes derived for the structural design are shown in Figures 3.4-5 and 3.4-6, respectively.

4.3 MACHINERY ARRANGEMENT -- The arrangement of the propulsion and lift machinery is shown in Figure 3.4-7. As shown in Figure 3.4-7, the propulsion engines, aft lift engines, and aft lift fans are located port and starboard in the sidehull regions. The forward lift engines and lift fans are located in the forward region of the main deck. The machinery arrangement provides the maximum isolation of noise and

Table 3.4-1. WLB-SES - Deck Area and Hull Volume Allocations

SPACE DESCRIPTION		WLB-SES		EXISTING CRAFT			
				180 FT WLB			
		FT²	FT²/MAN	FT²	FT²/MAN	FT²	FT²/MAN
BERTHING	CO Cabin	191	191	167	167		
	Officer	256	85	341	113.7		
	CPO	210	105	190	95		
	EM	946	22.5	683	16.3		
SANITARY	CO	39		24			
	Officer	48		49			
	CPO	60		39			
	EM	272		90			
MESS	Ward Room	198		223			
	CPO Mess and Lounge	152		134			
	EM Mess	264		259			
	EM Lounge	229		-			
COMMISSARY	Officer Pantry	36		49			
	Galley	275		132			
	Scullery	52		46			
	Cold Storage	139		124			
	Dry Food	144		140			
	Laundry	132		63			
	Barber	55		-			
	Ship Service	110		33			
	TOTAL	3808		2786			

Table 3.4-1. WLB-SES - Deck Area and Hull Volume Allocations (Cont'd)

SPACE DESCRIPTION	WLB-SES		EXISTING CRAFT			
			180 FT WLB			
	FT²	FT²/MAN	FT²	FT²/MAN	FT²	FT²/MAN
Pilothouse	318		263			
C^3	710		158			
Central Control Sta.	220		105			
Ship Offices	276		174			
General Stores	270		-			
Spare Parts	270		74			
Hawser and Refc. Equip.	263		47			
BSN Lkr.	230		391			
Hose Rack	105		54			
Cargo Hold	616		439			
EM Shop	-		41			
DC Shop	-		141			
DC Stores Lkr.	-		30			
ET Stores	-		30			
Unassigned	2734					
TOTAL	6012		1947			

OTHER EQUIPMENT:

<u>Water</u>
Required 58 Tons
Available (Tanks 1 & 2) = 67 x .95 x .98 = 62.4 Tons

<u>Fuel</u>
Required = 154 Tons
Available (Tanks 3, 4, 5, 6) = 210 x .95 x .98 = 196 Tons

<u>Cargo Hold</u>
Required = 4300 Ft³
Available = 5259 Ft³

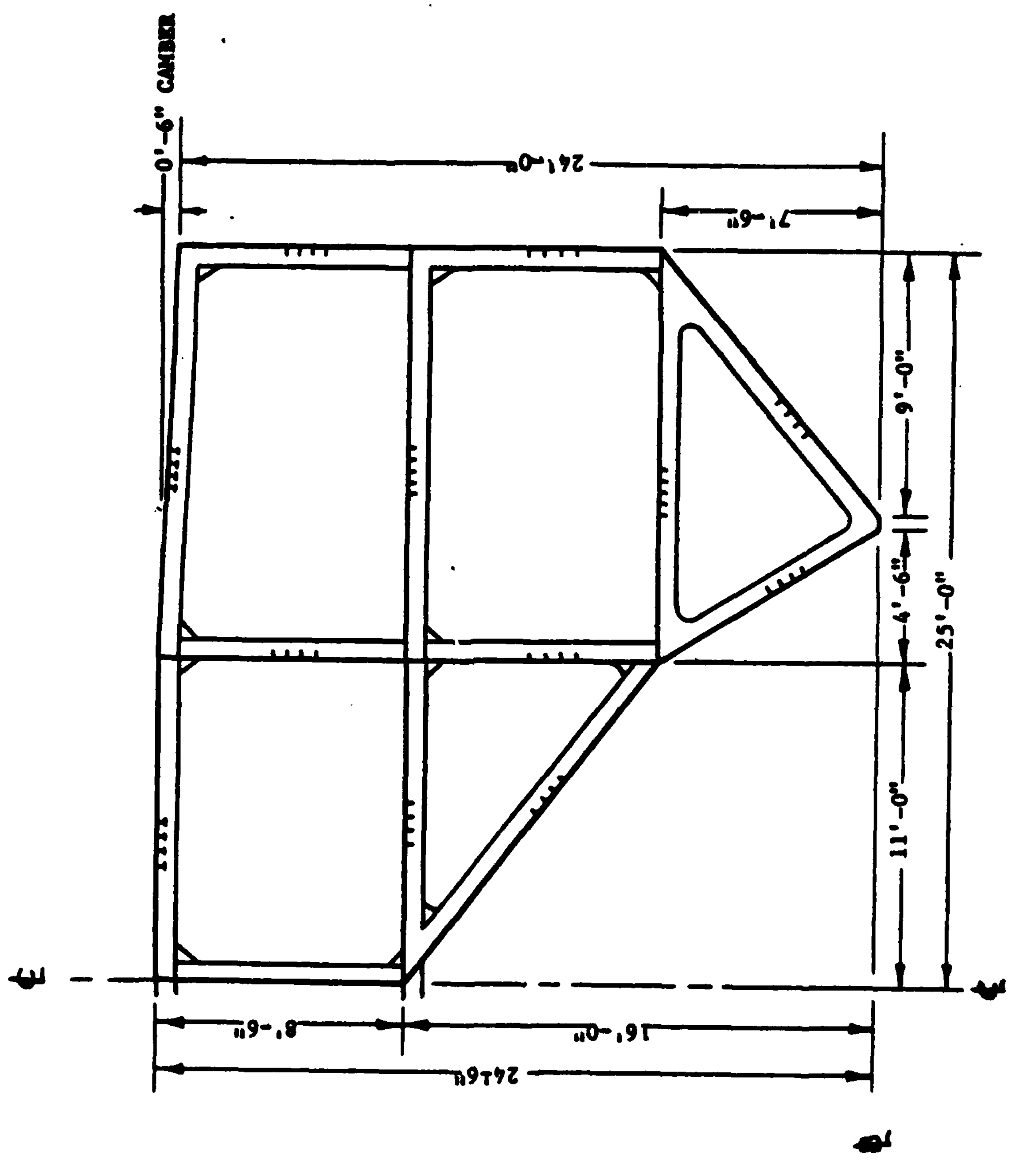


Figure 3.4-4. WLB-SES Midship Section

SLAM PRESSURES ARE NOT COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS (OTHER THAN SLAMMING) ARE COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS INCLUDE DECK LIVE LOADS: 75 PSF (TOP OF DK HSE)
150 PSF (LIVING, OFFICE SPACES)
200 PSF (MACHINERY SPACES)

USE 50% OF SLAM PRESSURE FOR FRAME DESIGN

SAFETY FACTORS	YIELD	ULT.
HULLBORNE + LOCAL LOADS	1.2	1.5
CUSHIONBORNE + LOCAL LOADS	1.2	1.5
SLAMMING PRESSURES	1.0	1.2

PERMANENT SET TO A MAXIMUM OF PLATE THICKNESS IS ALLOWED

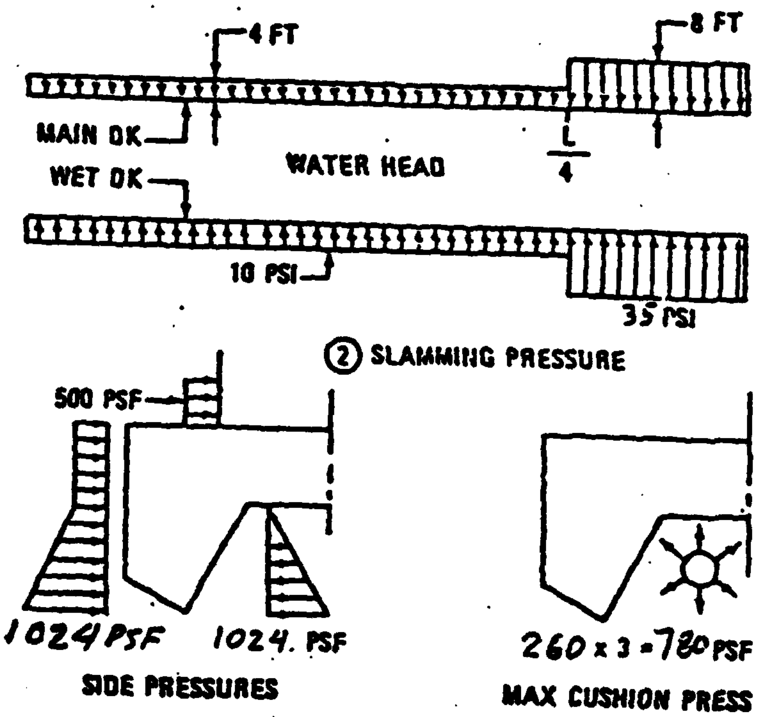
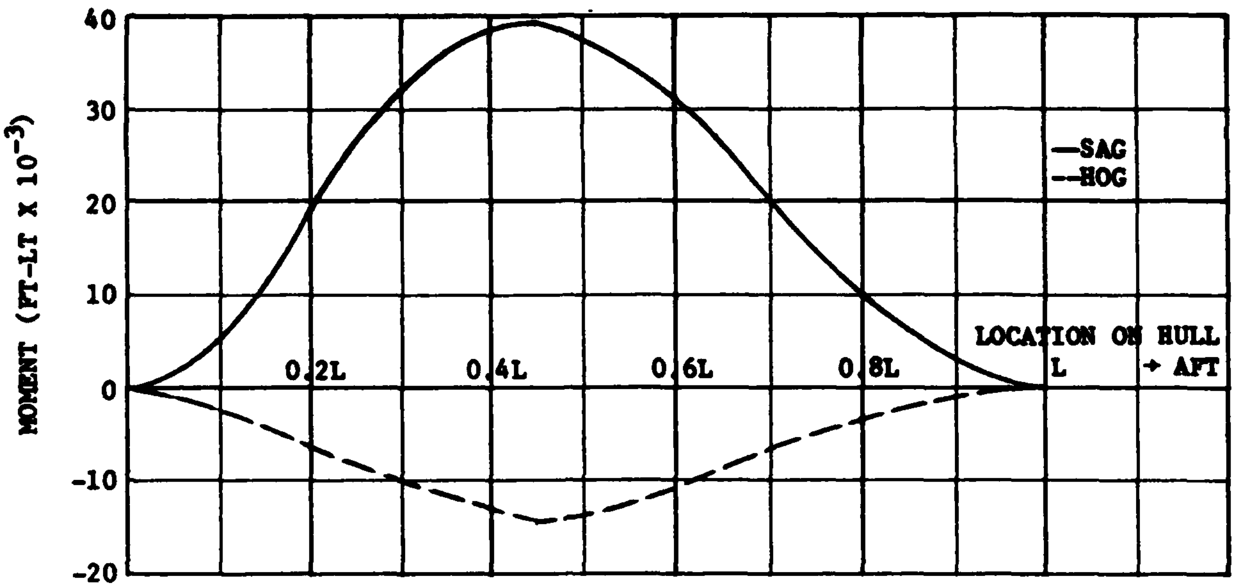
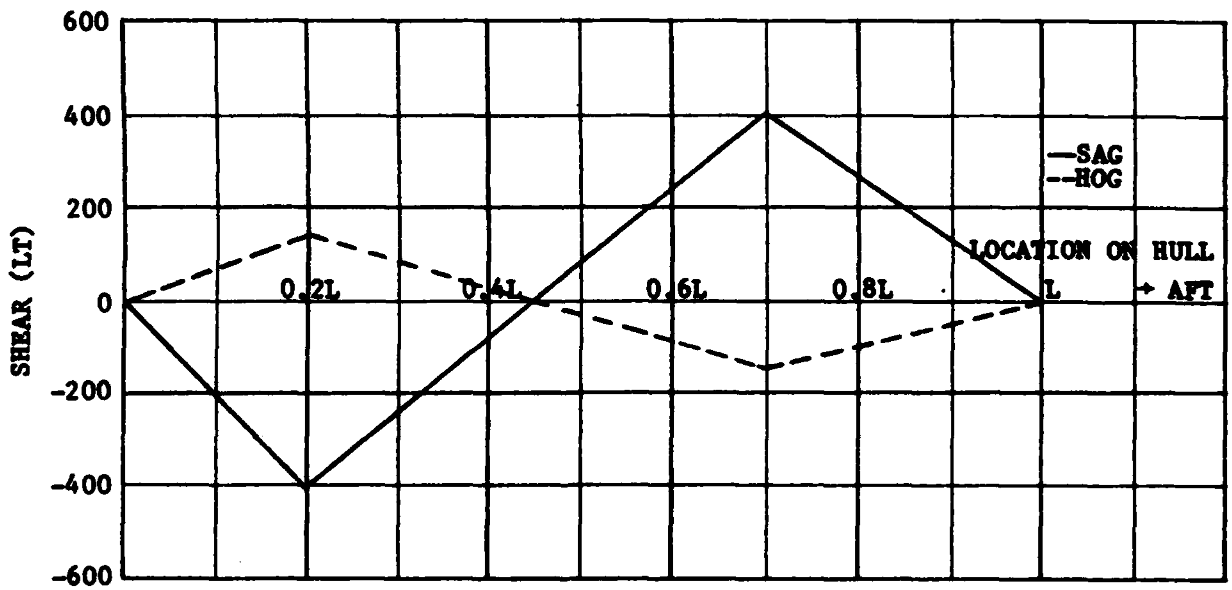


Figure 3.4-5. WLB-SES Hull Design Criteria



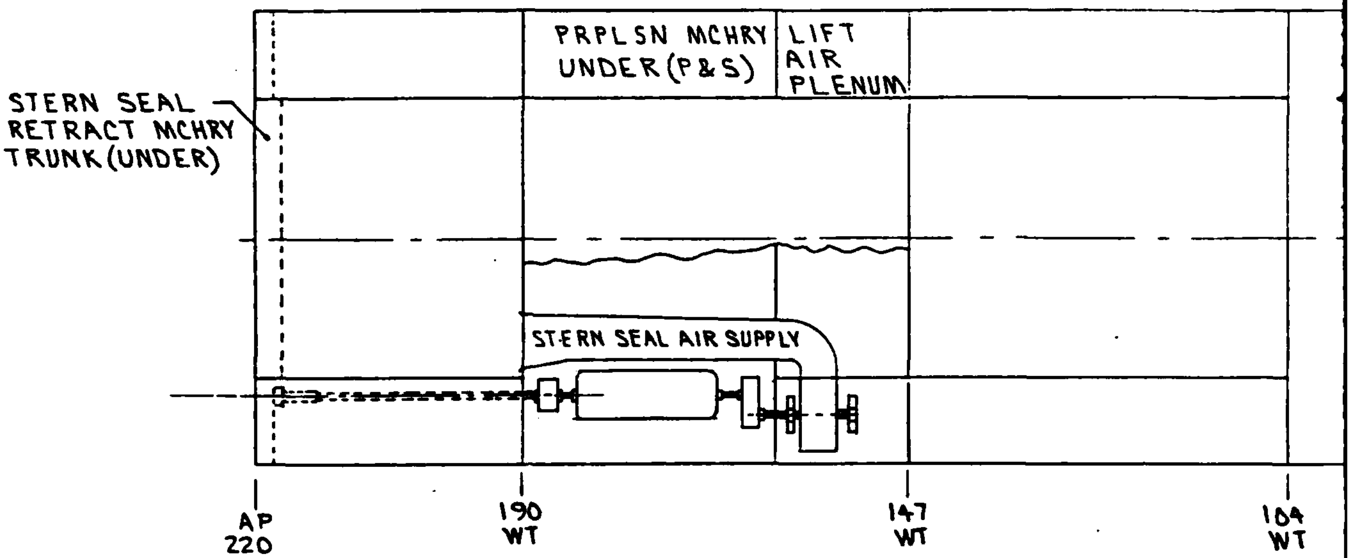
HULLBORNE BENDING MOMENT



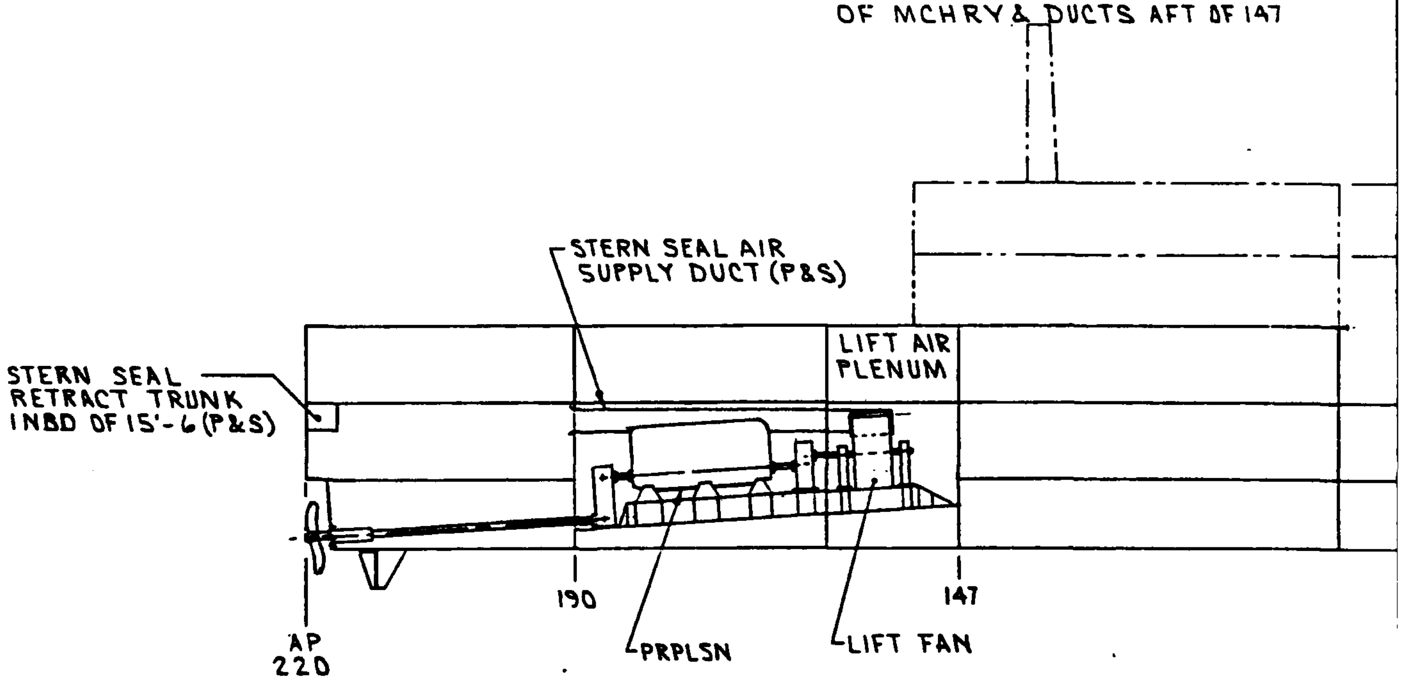
HULLBORNE SHEAR

Safety Factors - SF Yield = 1.2
SF ULT = 1.5

Figure 3.4-6. WLB-SES Design Shear and Bending Moment Envelopes



MAIN DECK PLAN
DECK PLATING REMOVED IN WAY OF MCHRY & DUCTS AFT OF 147



PROFILE @ 18'-0 OFF CL

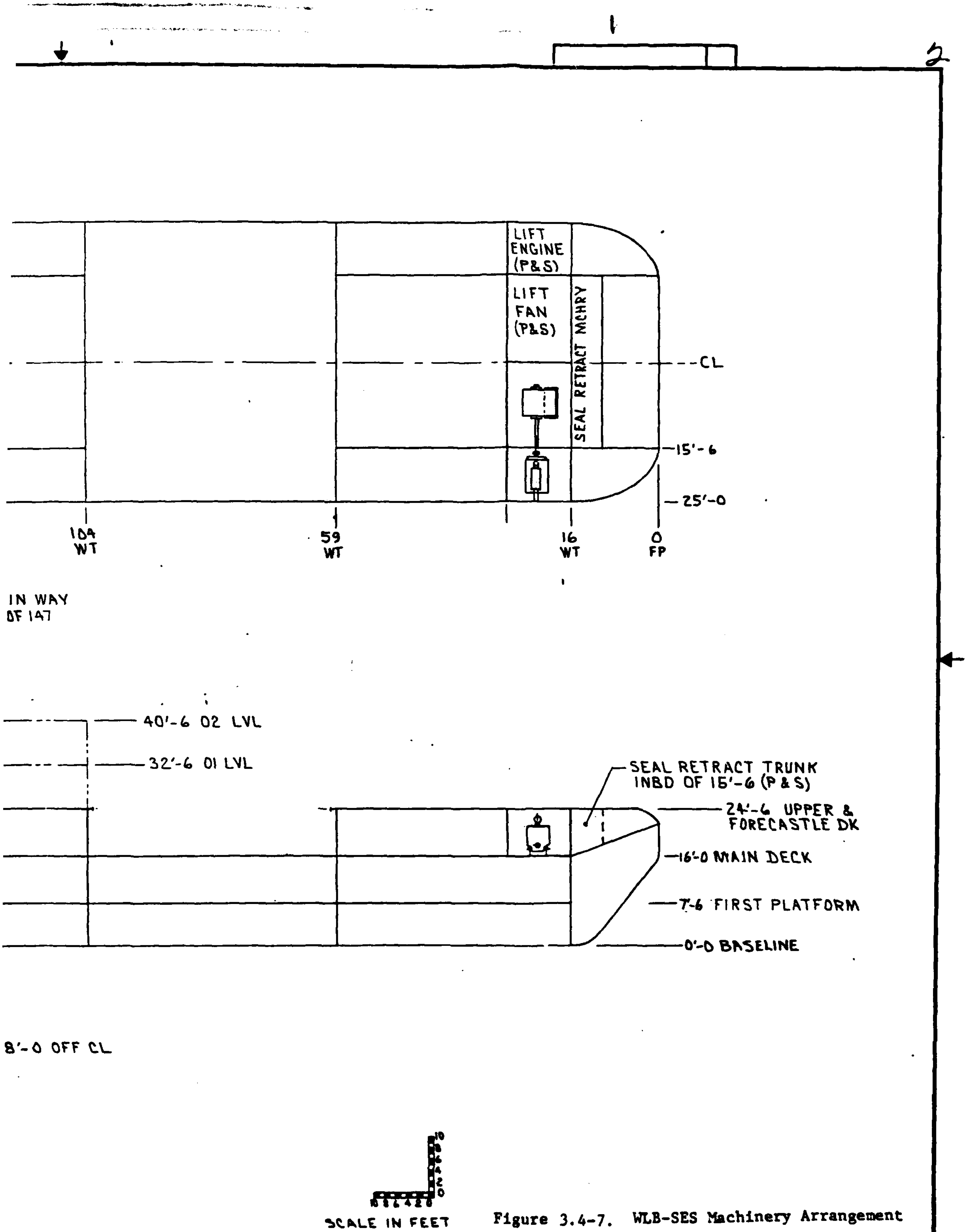


Figure 3.4-7. WLB-SES Machinery Arrangement

vibration producing machinery from habitability spaces attainable within the constraints of hull size and other arrangement requirements. The machinery isolation provided by the arrangement, coupled with the installation of vibration isolation mounts for all machinery and acoustical treatment on machinery space boundaries, should ensure low vibration and noise levels in all habitability spaces.

The cushion seal installation consists of a transversely stiffened bow seal and a multiple loop stern seal. Both bow and stern seals are provided with retraction systems. The bow and stern seals are shown in Figure 3.4-8 and 3.4-9, respectively. The seal material properties are listed in Table 3.4-2.

4.4 ELECTRICAL SYSTEM -- The electrical power system consists of three 150 KW, 60 Hz diesel generators connected in a ring bus distribution system. The power provided by the two operating diesel engines is adequate to satisfy the ship's electrical power requirements under all operating conditions. The third generator provides standby power. Transformer rectifiers of a type proven in service aboard Navy ships are used to provide 28 volt DC for control and actuator power, as required. A battery bank is used to provide emergency and/or uninterruptible power. Two solid state 60 Hz/400 H2 frequency convertors are employed to provide 400 Hz power as required with one operational and the other on standby under normal operating conditions. A diagram of the electrical power distribution concept is shown in Figure 3.4-10.

4.5 COMMAND COMMUNICATION AND CONTROL -- Three command communication and control spaces are provided:

1. Pilot House located on the 01 Level.
2. Command Communication and Control Center located on the 01 level immediately aft of the Pilot House.
3. Central Control Room located aft on the Main Deck.

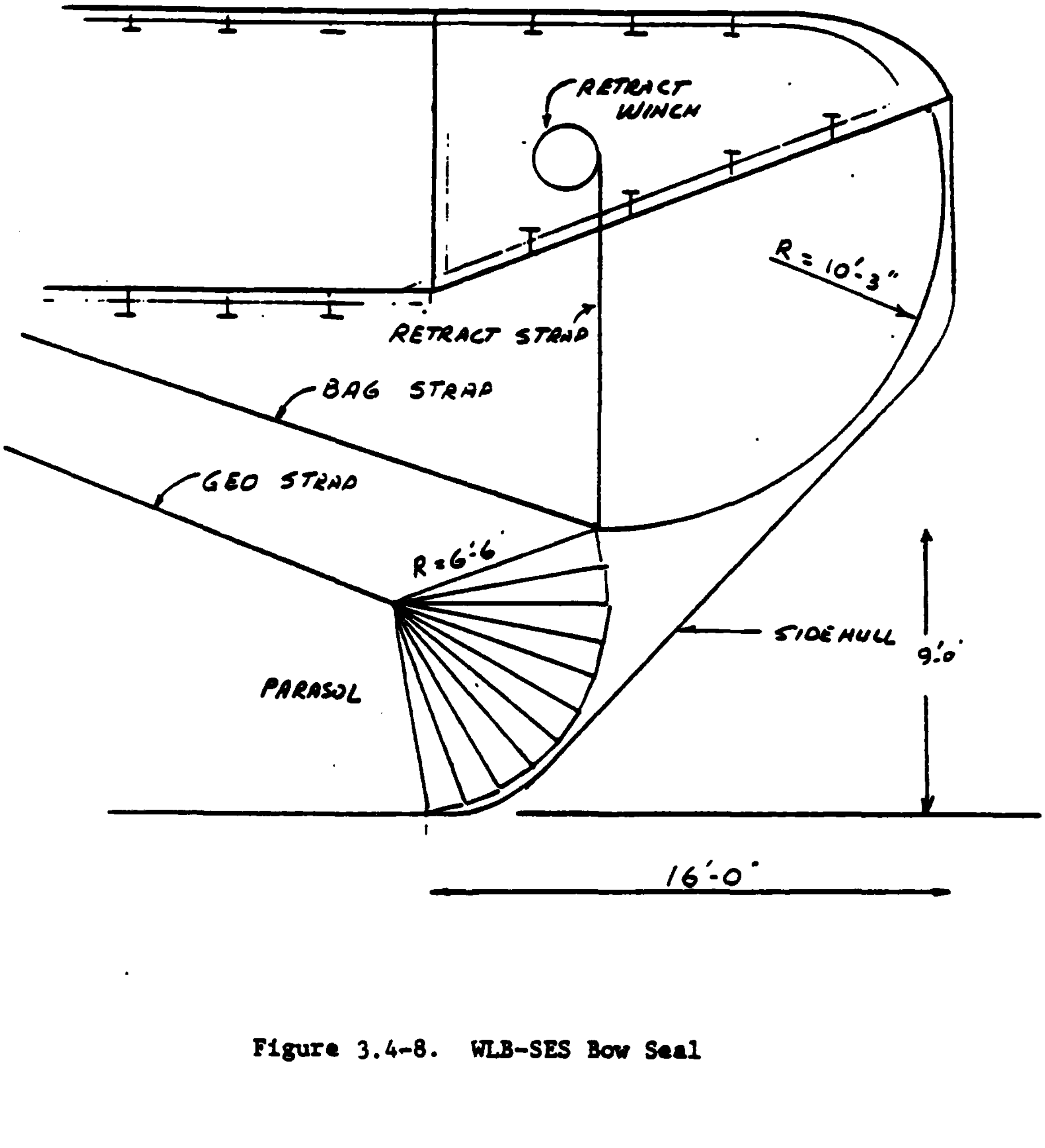


Figure 3.4-8. WLB-SES Bow Seal

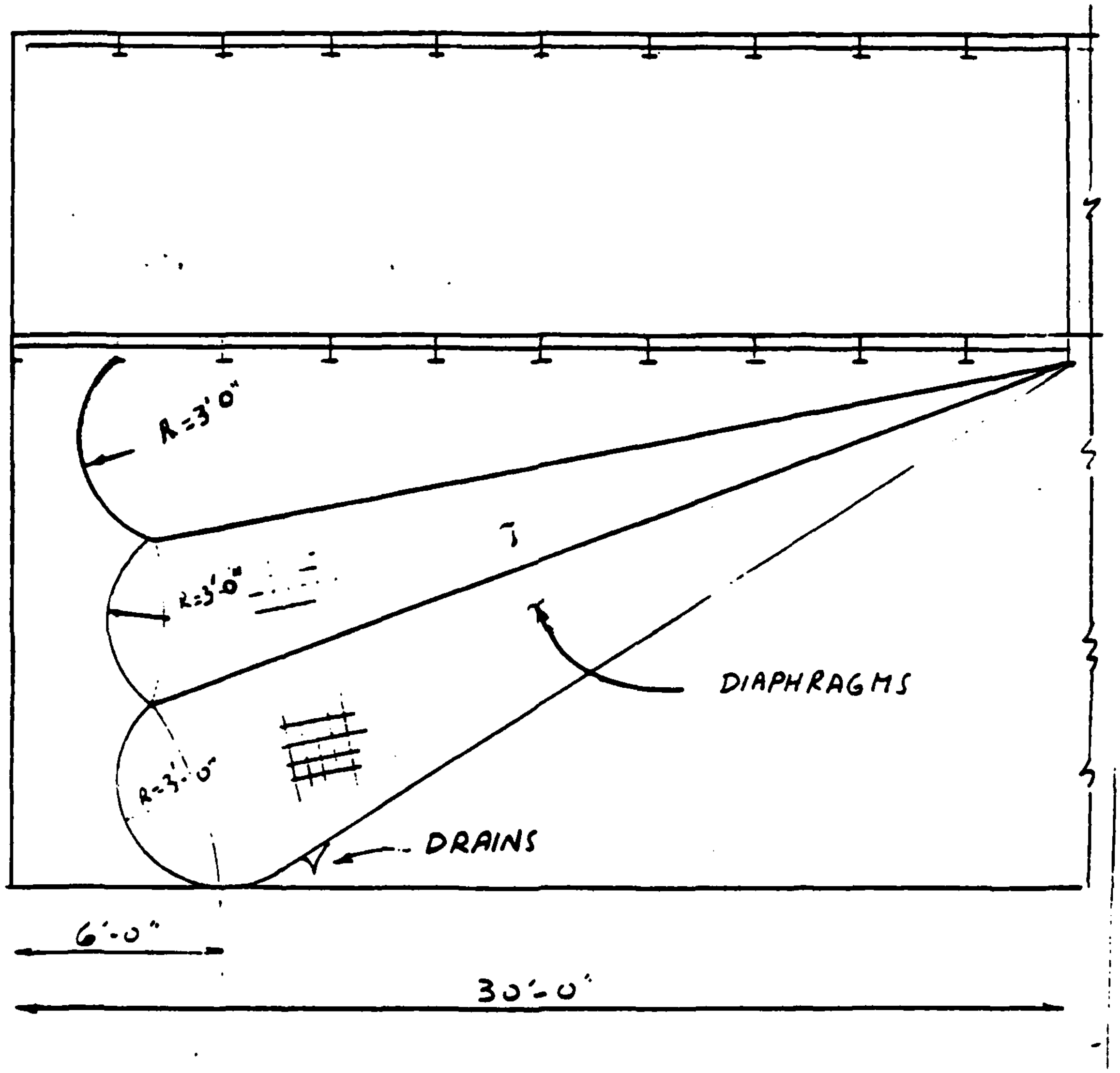


Figure 3.4-9. WLB-SES Stern Seal Schematic

Table 3.4-2. WLB-SES Seal Materials

MATERIAL CHARACTERISTICS	BAG		PARASOL (NOTE (1))
	BOW	STERN	
Fabric Type	Nylon 3x4 (Basket Weave)	Nylon 3x4 (Basket Weave)	Nylon 3x4 (Basket Weave)
Coating Type (2)	Neoprene Base Rubber	Neoprene Base Rubber	Neoprene Base Rubber
Material Weight	90 Oz/Yd^2	90 Oz/Yd^2	90 Oz/Yd^2
Tensile Strength — Warp	1200 ply	1200 ply	1200 ply
Tensile Strength — Fill	1200 ply	1200 ply	1200 ply
Tear Strength	200 ply	200 ply	200 ply

Notes:

(1) Parasol stiffening elements (battens) have the following dimensions:

Thickness = 0.1 In.

Width = 1-1/2 In.

Length ≈ 12 In

The battens are made from glass reinforced plastic (Scotchply 1002) The fibers are unidirectional and are parallel to the long side of the batten. The batten material properties are as follows:

Flexural Strength	= 165,000 psi	Room Temp. and Dry
Modulus in Flexure	= 5.3×10^6 psi	Room Temp. and Dry
Tensile Strength	= 160,000 psi	Room Temp. and Dry
Specific Gravity	= 1.8	

(2) Alternate seal coating may be Chemigum vinyl (Goodyear M-521) fabric type, may be Goodyear H391.

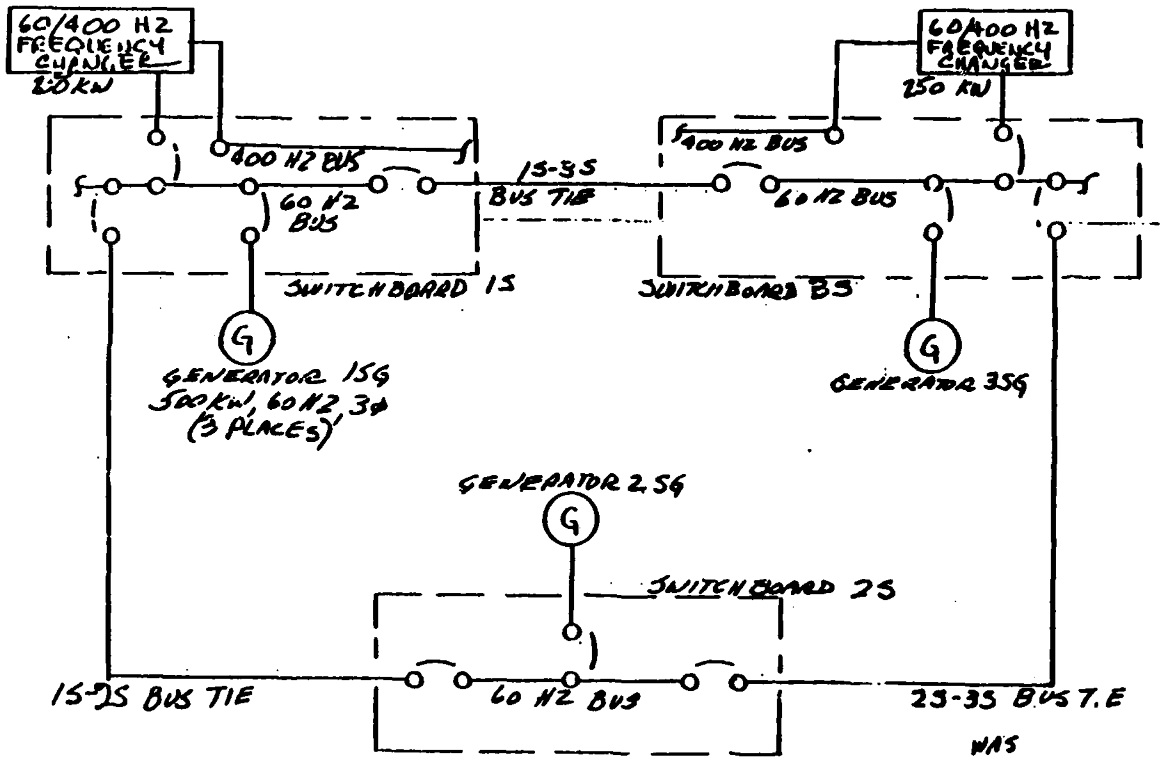


Figure 3.4-10. WLB-SES Power System Distribution Diagram

The Pilot House serves as the primary control station for ship maneuvering, navigation, and collision avoidance. Limited control of propulsion and lift machinery is provided in the Pilot House to the extent required for ship handling.

The Command Communication and Control Center serves as the primary control control station for exterior and interior communications and for tactical command.

The Central Control Room serves as the primary control station for all ship engineering and auxiliary support functions including control and monitor capability for propulsion, lift, electrical and auxiliary machinery and damage control.

A certain amount of commonality is necessary between the control system functions assigned to the Pilot House and the Central Control Room. Vital ship functions such as propulsion/lift engine throttle control and communications capability, are duplicated between the two spaces for reliability and safety. Additionally, certain alarms are presented in summary fashion at the Pilot House, with functional control of the monitored equipment being assigned to the Central Control Room.

Redundancy is provided for vital functions with (1) control consoles in the Pilot House and the Central Control Room, (2) spatially separated dual remote control paths, and (3) local control.

Navigation equipment is listed in Table 3.4-3.

5. WEIGHT ESTIMATE

The weight estimate is summarized in Table 3.5-1. The lightship weights shown in Table 3.5-1 were derived from parametric analysis of other SES designs and the use of catalog information for major equipment items. Weights for mission related equipment and variable load items were derived from the design requirements defined in Section 3.

Table 3.4-3. WPC-SES Navigation and Communication Equipment

NAVIGATION EQUIPMENT	COMMUNICATIONS EQUIPMENT
• RADAR (COLLISION AVOIDANCE) (TWO SYSTEMS) • LORAN-C • SATNAV • RDF • GYRO • FATHOMETER • SPEED LOG • WIND SPEED AND DIRECTION	• VHF (TWO SYSTEMS) • SSB-HF (TWO SYSTEMS) • INTERIOR COMMUNICATION • INTERIOR TELEPHONE

Table 3.5-1. WLB-SES Weight Estimates

SWBS	ITEM	LONG TONS
100	Hull Structure and Seals	300.0
200	Propulsion and Lift Systems	85.0
300	Electric Power Generation and Distribution System	25.0
400	Command and Surveillance System	30.0
500	Auxiliary Subsystems	30.0
600	Outfit and Furnishings	30.0
700	Combat System	25.0
	Estimated Lightship (without margin)	525.0
	Design and Construction Margin (10%):	53.0
	Design Lightship	578.0
F10	F10 - Personnel	11.6
F23	F23 - Ordnance Delivery Systems	0
F30	F30 - Stores	2.0
F42	F42 - Helo Fuel	0
F42	F42 - Ships Fuel	154.0
F50	F50 - Liquids	5.0
/	Mission Related Equipment (Payload)	50.0
	Full Load Displacement (FLD)	800.6

6. PERFORMANCE

The performance characteristics in terms of power, speed, range, ride quality, hydrostatic characteristics and stability are summarized below.

6.1 SPEED, DRAG AND SEA STATE RELATIONSHIPS -- The speed, drag, and power relationships for cushionborne operation at various craft displacements in Sea States 0 and 3, are shown in Figure 3.6-1 and 3.6-2, respectively.

6.2 RANGE CAPABILITY -- The range capability for 20-knot cushionborne and 11.5-knot hullborne operation in Sea State 0 is shown in Figure 3.6-3.

6.3 SHIP MOTIONS AND RIDE QUALITY -- The ship motions characteristics at various speed and sea states relative to the U. S. Navy 30-minute and 4-hour ride quality criteria are shown in Figures 3.6-4 through 3.6-7. Note that the characteristics shown are representative of head sea conditions. Some improvement in ride quality may be accomplished by adjustment of the ship's heading to avoid the head sea condition.

6.4 HYDROSTATIC CHARACTERISTICS -- The hydrostatic characteristics, as derived from the lines drawing shown in Figure 3.3-2, are presented in Figures 3.6-8 through 3.6-14.

6.5 INTACT STABILITY -- The intact stability characteristics in the full load condition and burned out condition are shown in Figures 3.6-15 and 3.6-16, respectively. As shown in the figures, the craft satisfies the intact stability criteria of DDS 079-1, "Stability and Buoyancy of U. S. Naval Surface Ships", in both conditions. The assessment relative to hoisting heavy overside weights is shown in Figure 3.6-17.

6.6 DAMAGE STABILITY -- The assessment of stability under various conditions of two compartment damage is shown in Figures 3.6-18 through 3.6-27. As shown, the craft satisfies the requirements of DDS 079-1 under all damage conditions investigated. The assessment was based upon an intact full load displacement condition. A permeability of ninety-five percent was assumed for all areas subject to flooding.

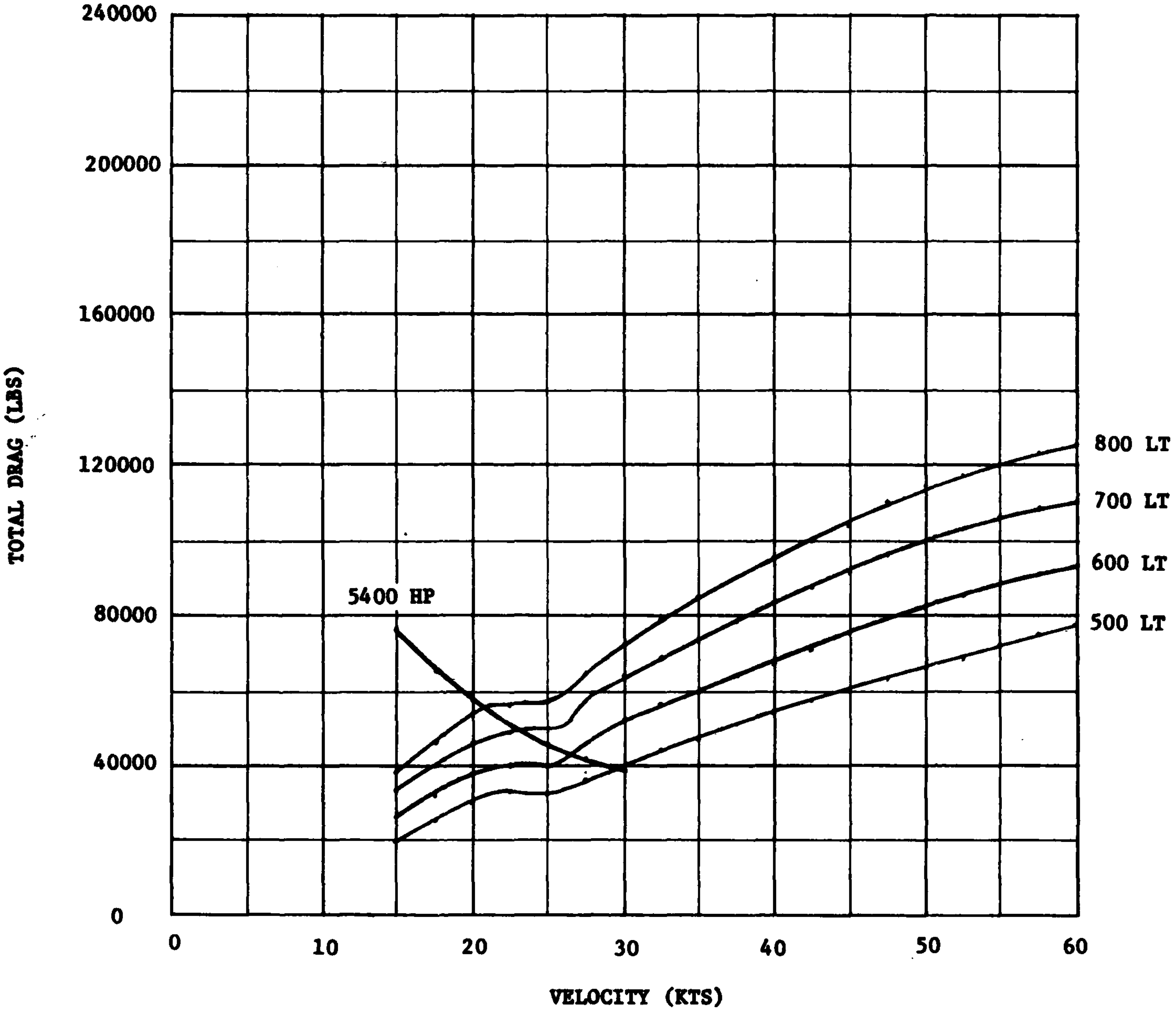


Figure 3.6-1 WLB-SES Speed-Drag Curves - Sea State 0

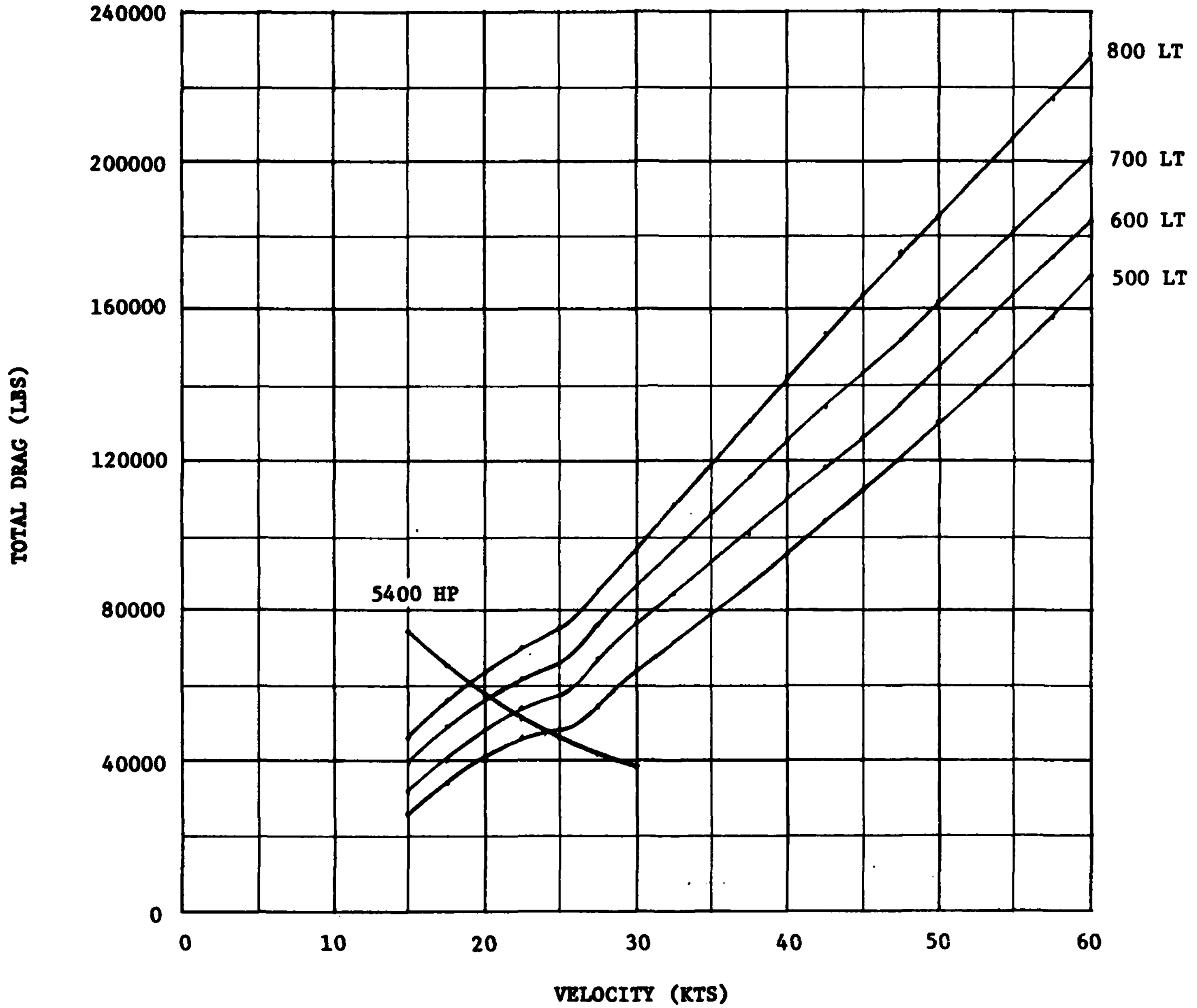


Figure 3.6-2. WLB-SES Speed-Drag Curves - Sea State 3

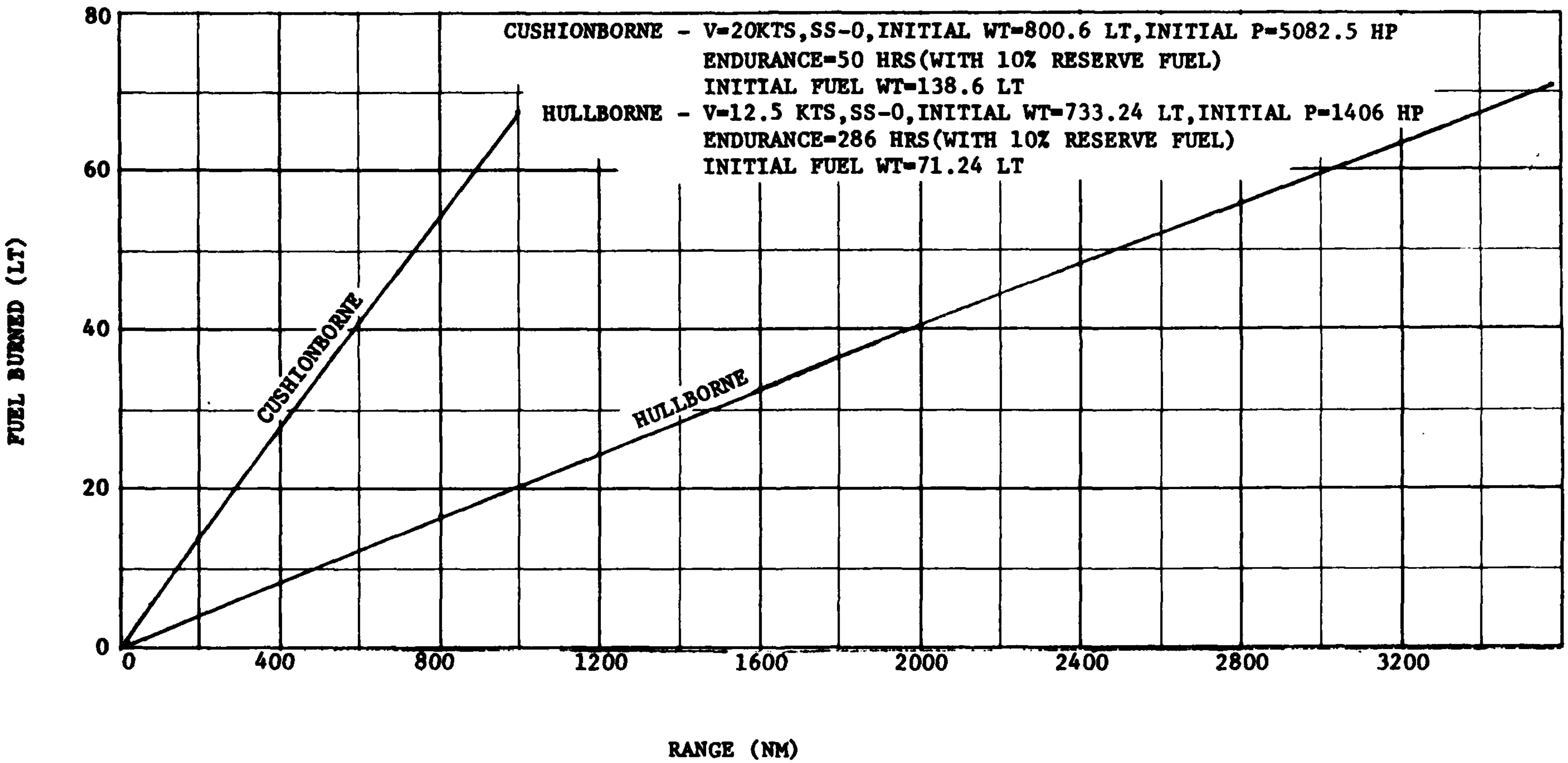


Figure 3.6-3. WLB-SES Range Capability

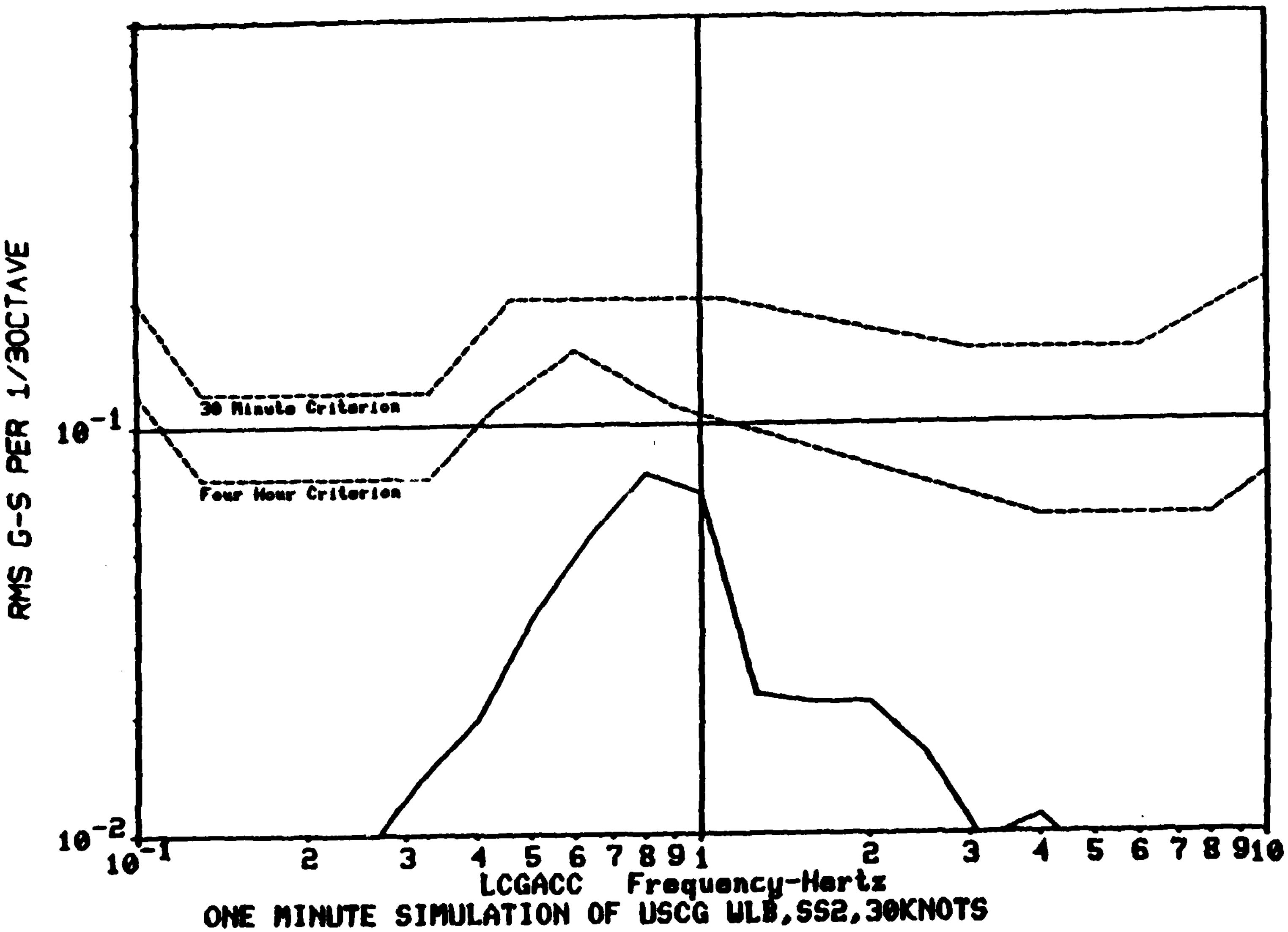


Figure 3.6-4. WLB-SES Ride Quality - 30 Knots - Sea State 2 - Cushionborne with Ride Control

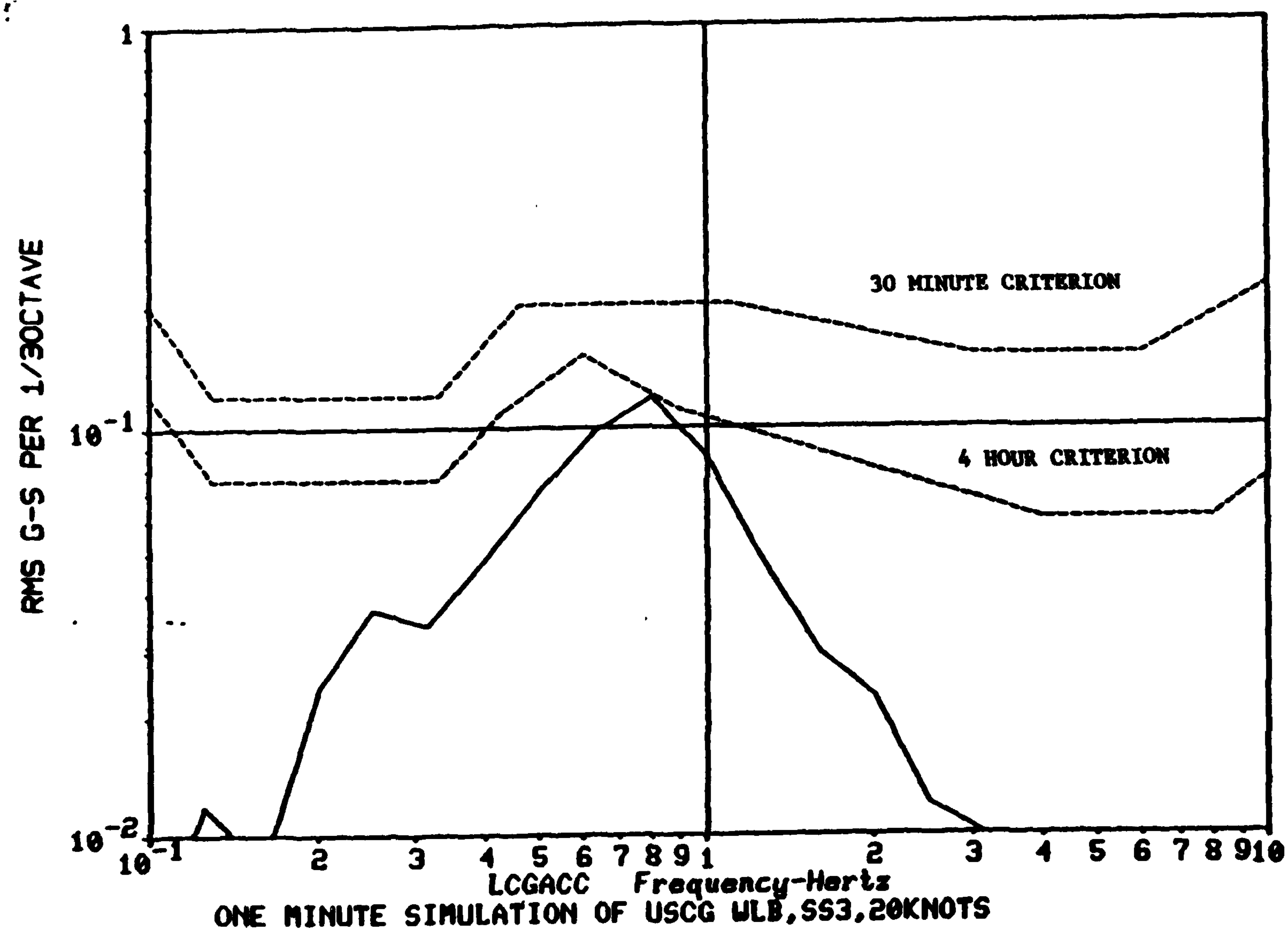


Figure 3.6-5. WLB-SES Ride Quality - 20 Knots - Sea State 3 - Cushionborne with Ride Control

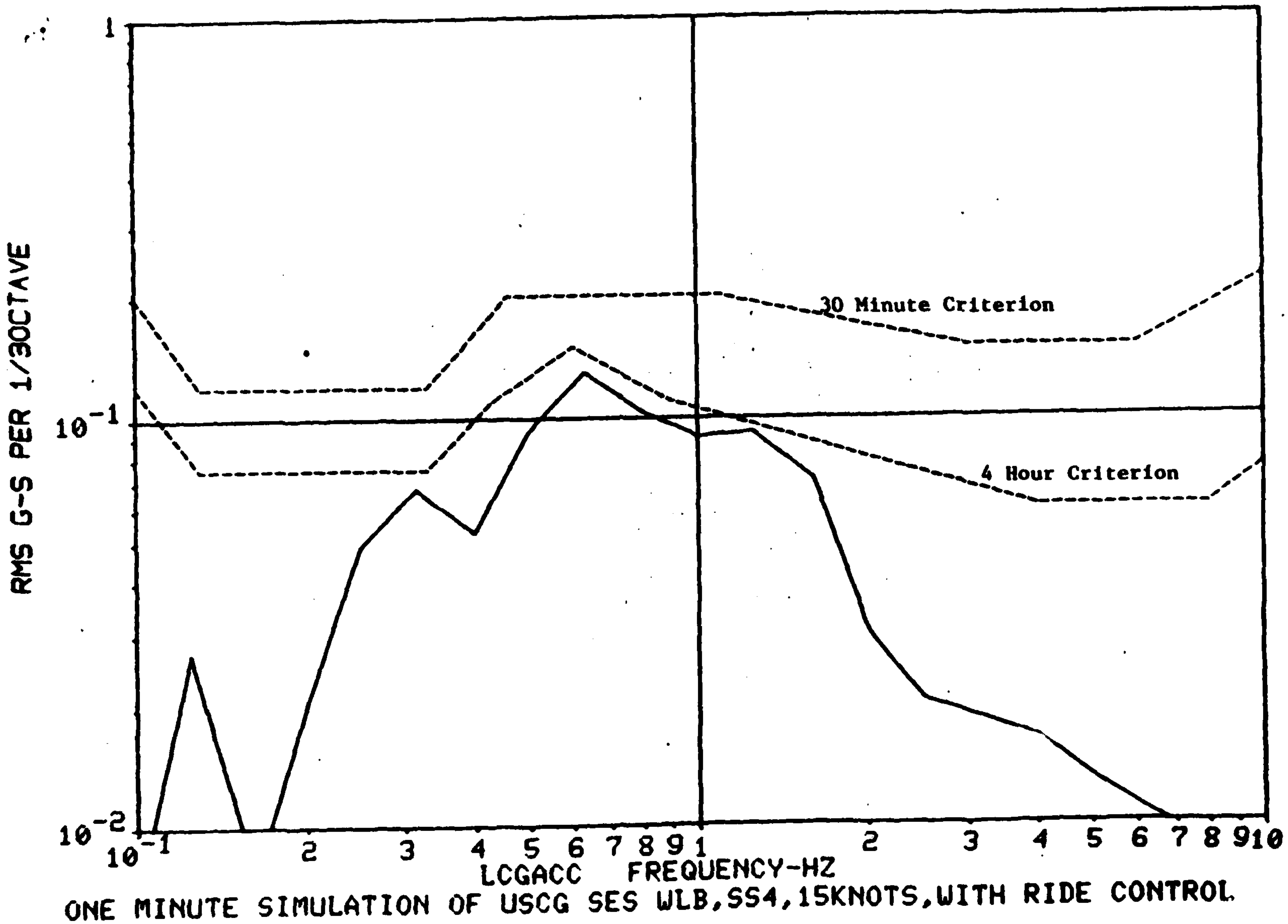


Figure 3.6-6. WLB-SES Ride Quality - 15 Knots - Sea State 4 - Cushionborne with Ride Control

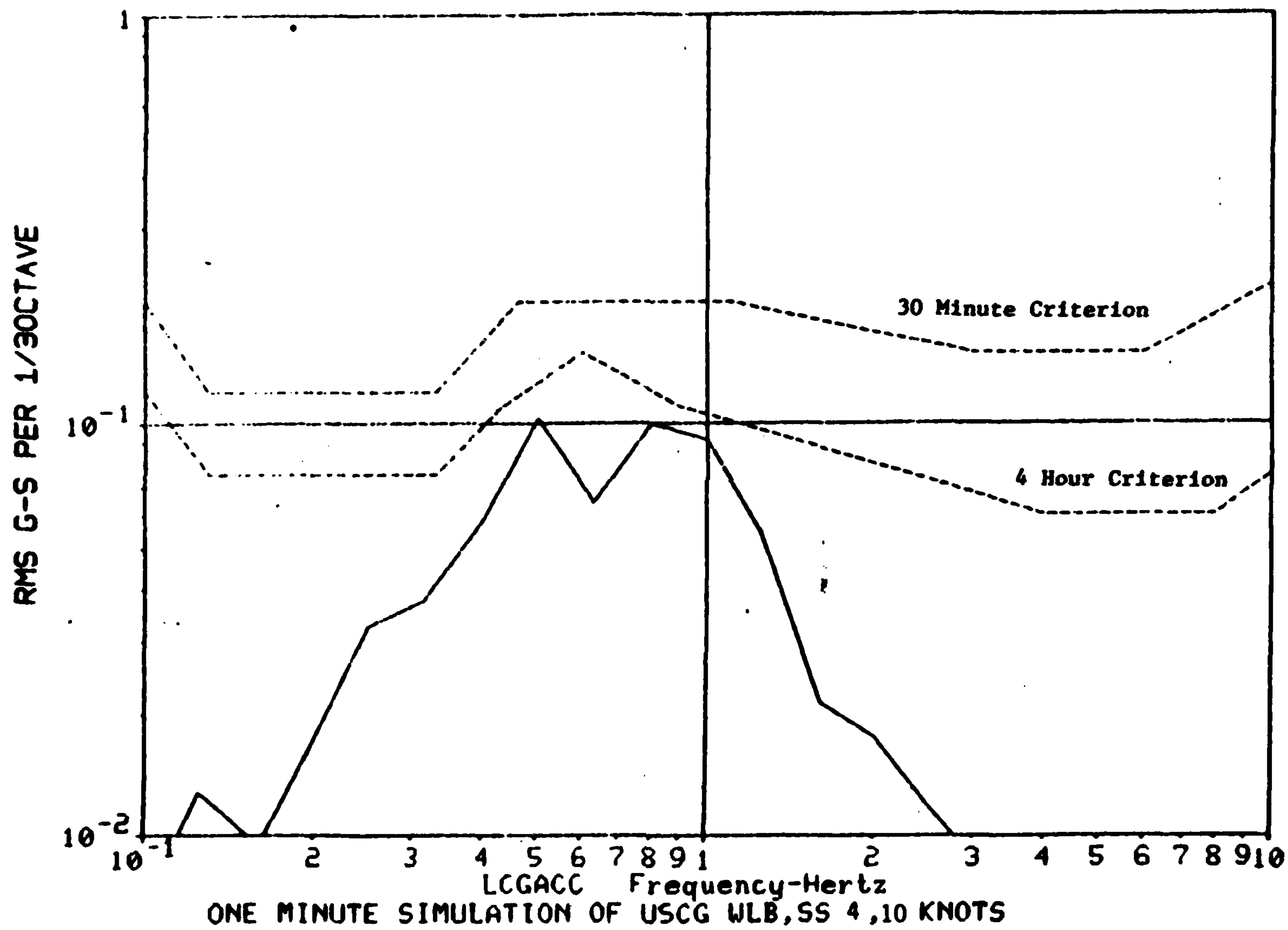


Figure 3.6-7. WLB-SES Ride Quality - 10 Knots - Sea State 4 - Cushionborne with Ride Control

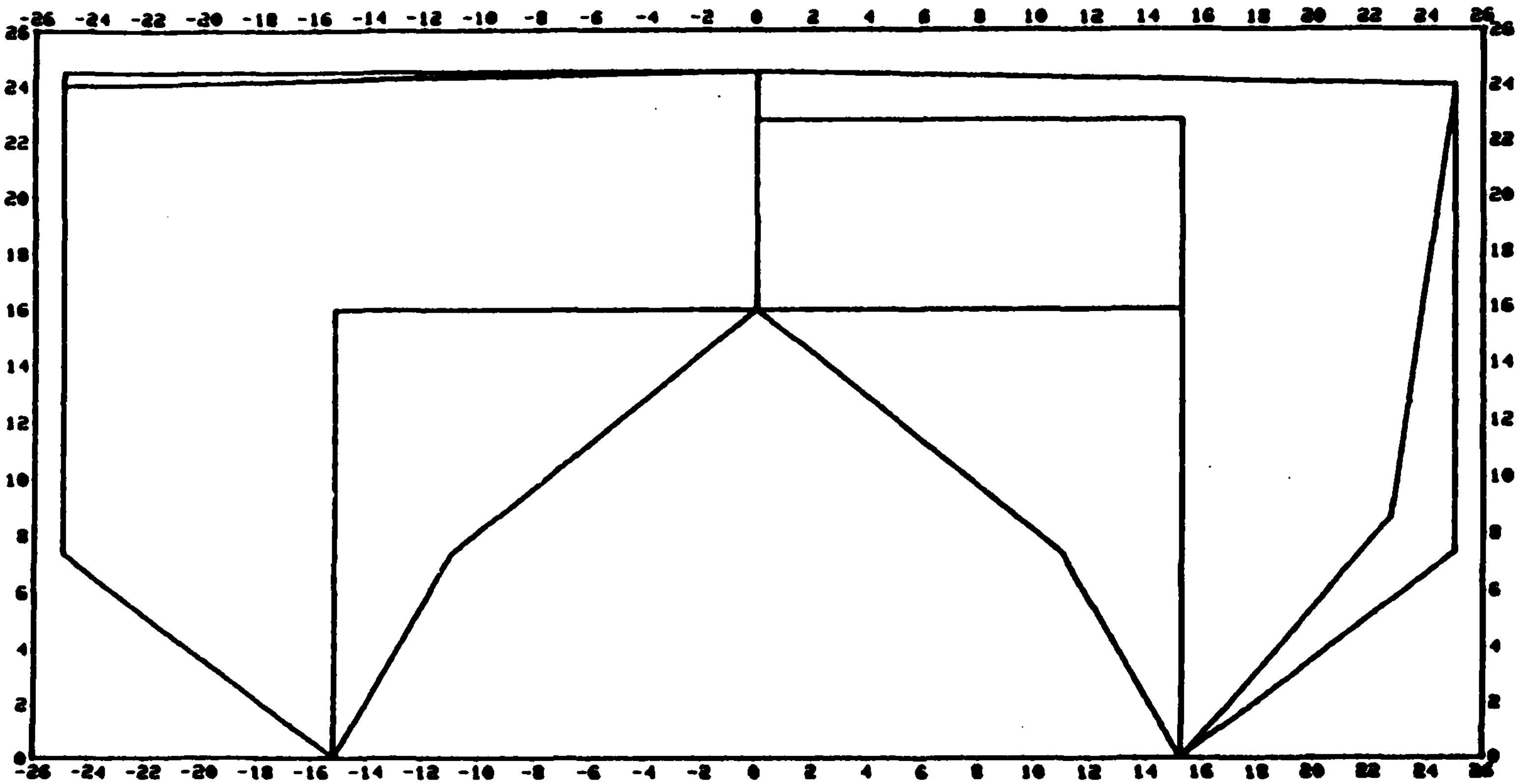


Figure 3.6-8. WLB-SES Hydrostatic Analysis - Transverse Section

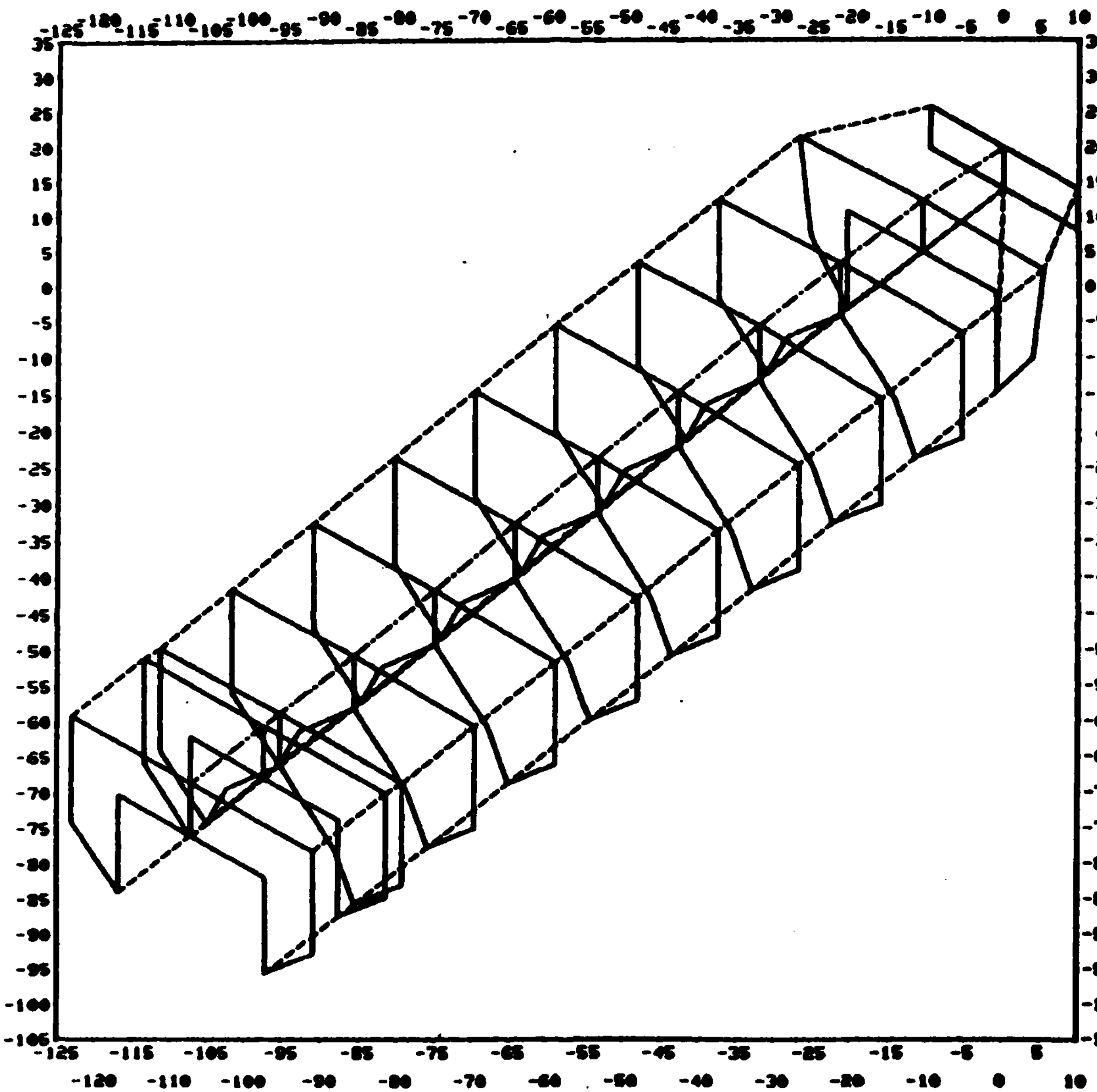


Figure 3.6-9. WLB-SES Hydrostatic Analysis - Hull Geometry

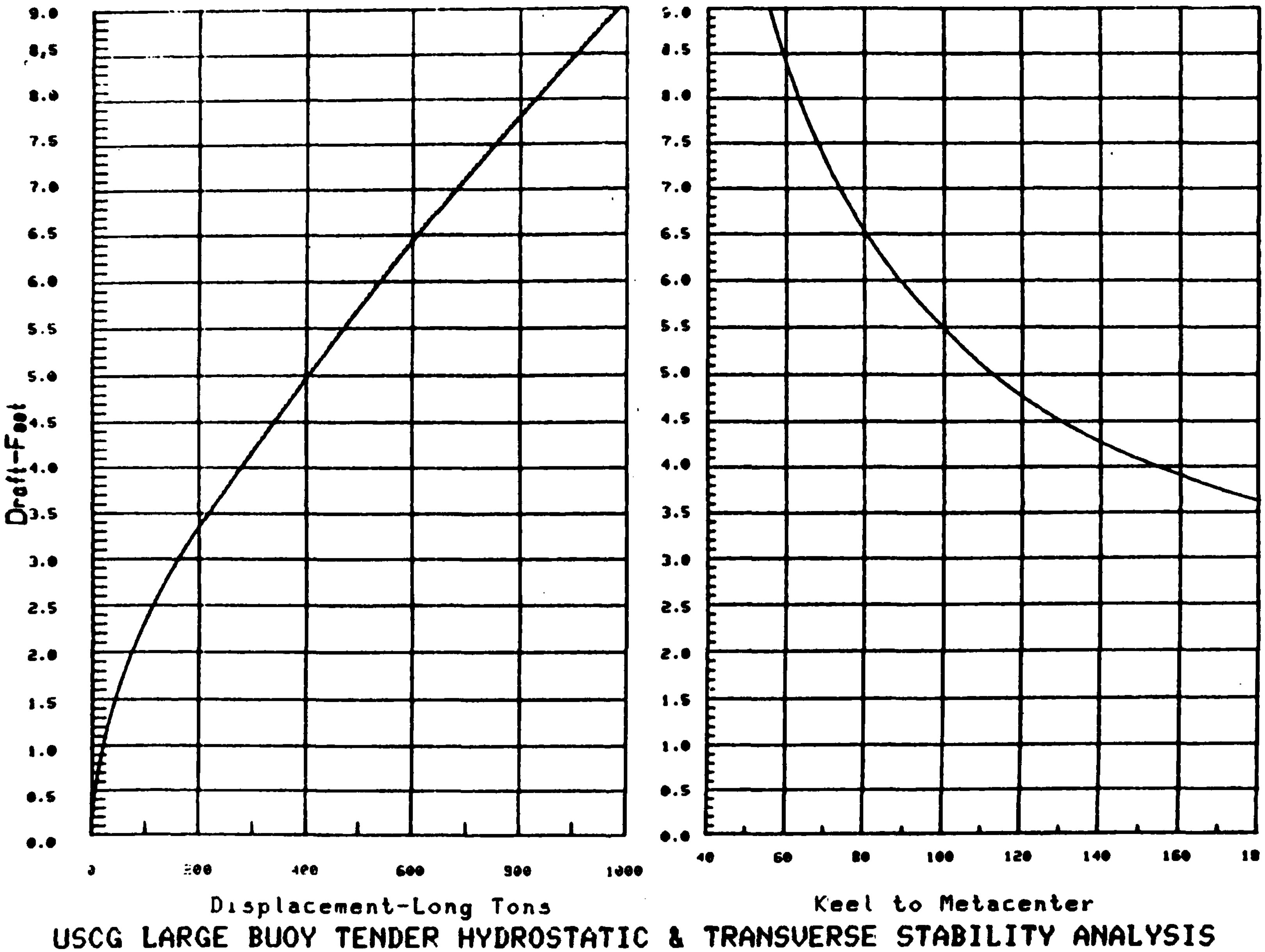
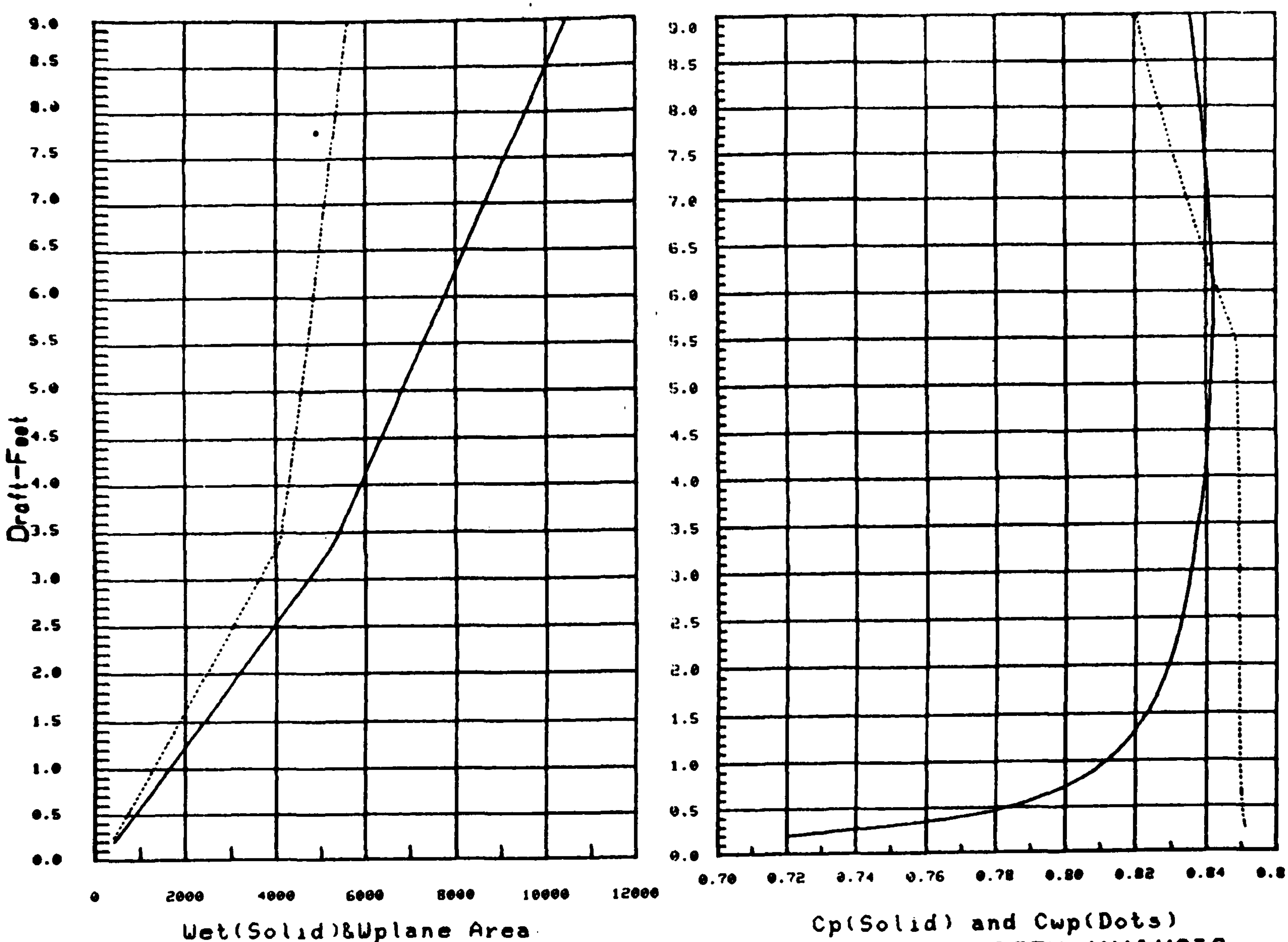


Figure 3.6-10. WLB-SES Displacement, Draft, and Transverse Metacenter



USCG LARGE BUOY TENDER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 3.6-11. WLB-SES Waterplane Area, Prismatic Coefficient and Waterplane Area Coefficient

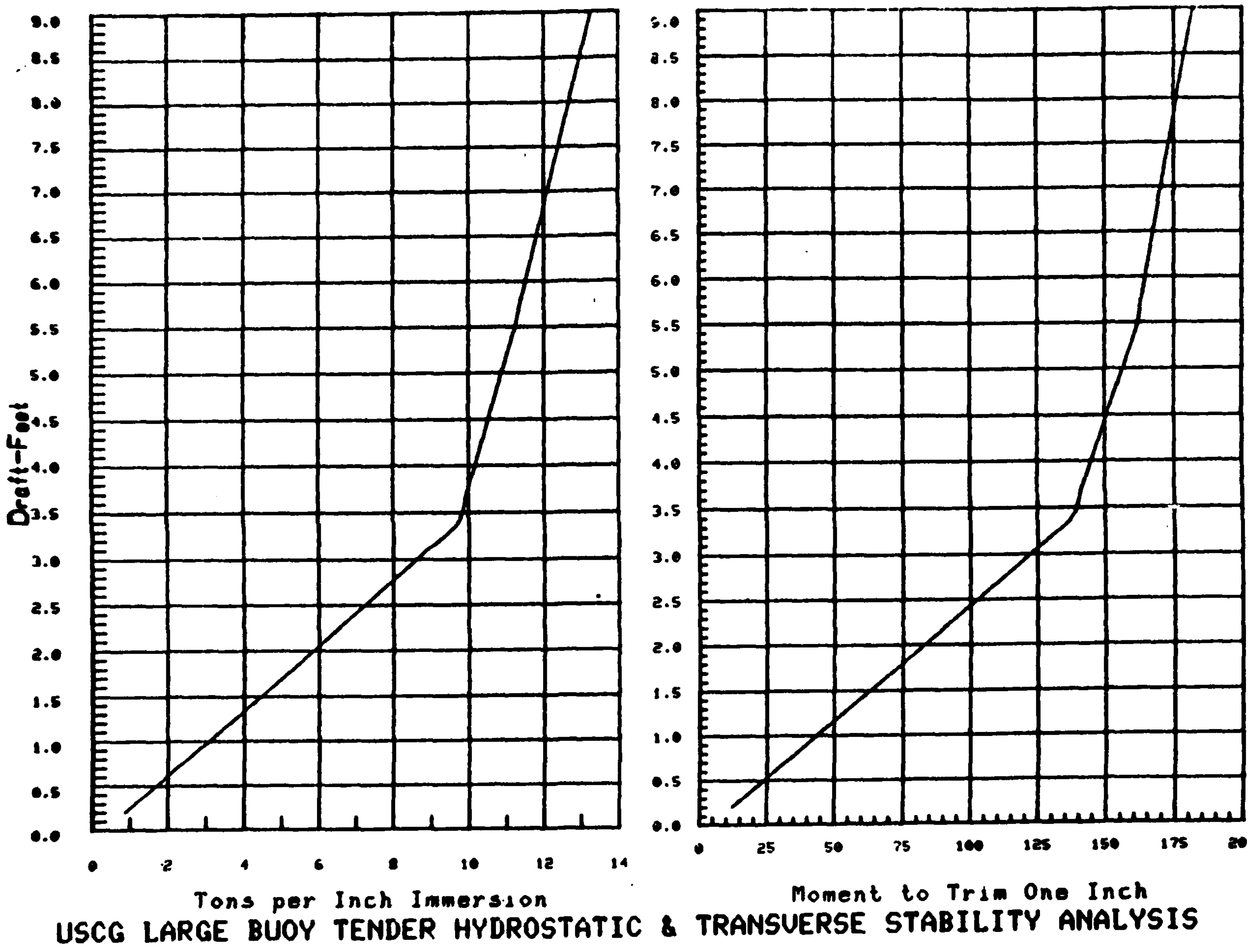


Figure 3.6-12. WLB-SES Tons Per Inch Immersion and Moment to Change Trim One Inch

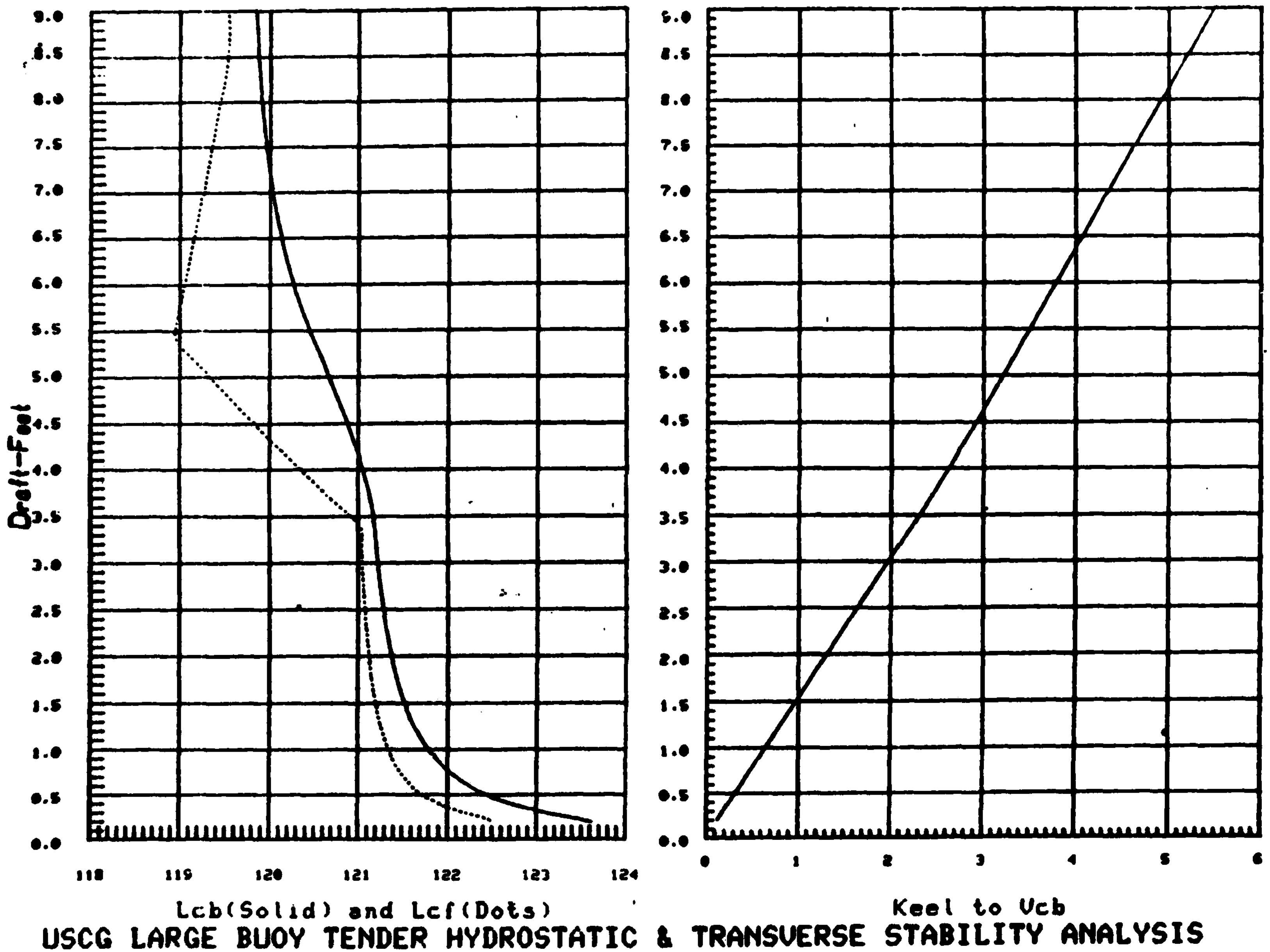


Figure 3.6-13. WLB-SES LCB, LCF and VCB

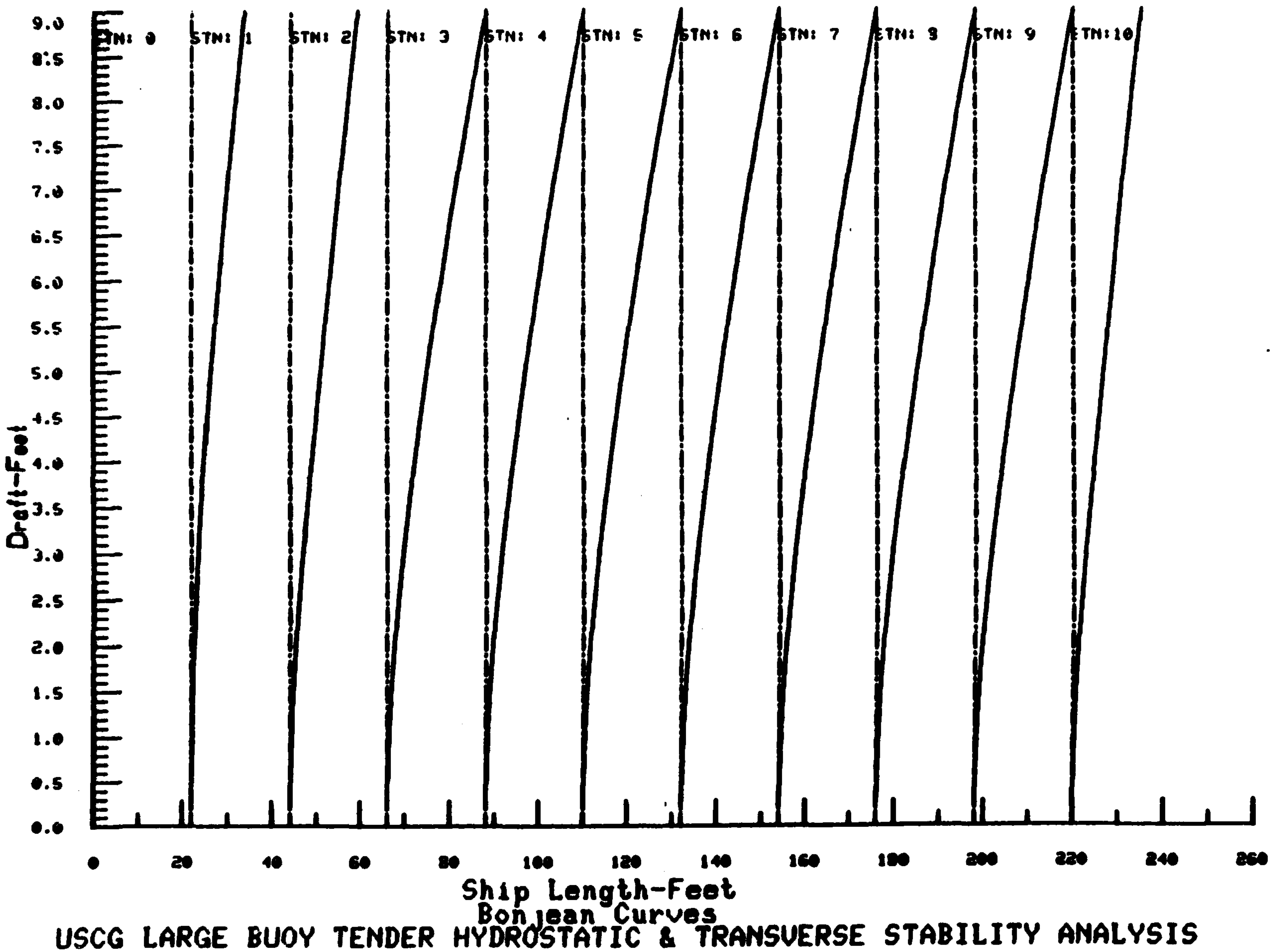


Figure 3.6-14. WLB-SES Bonjean Curves

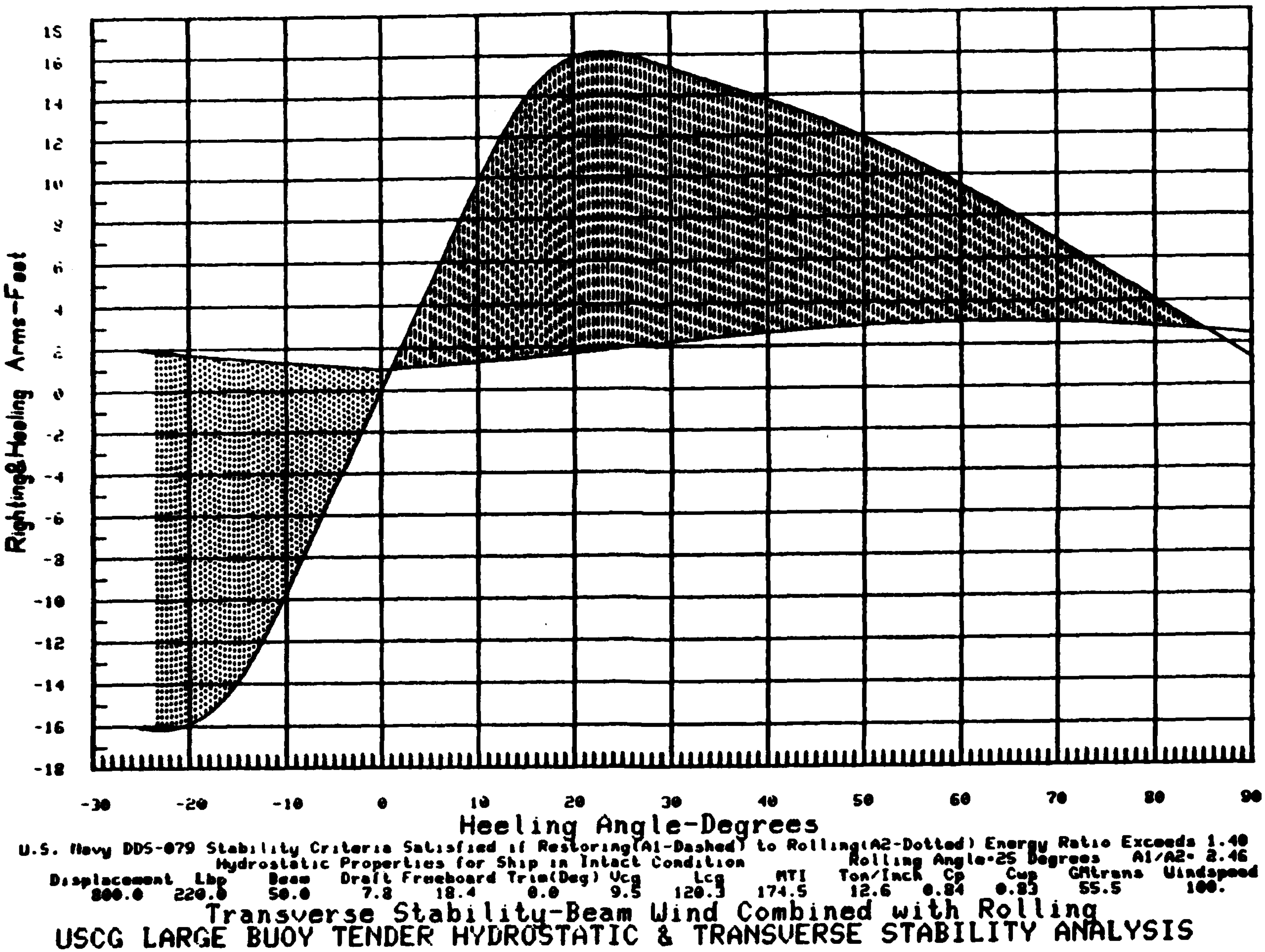


Figure 3.6-15. WLB-SES Intact Stability Wind Heel Full Load Condition

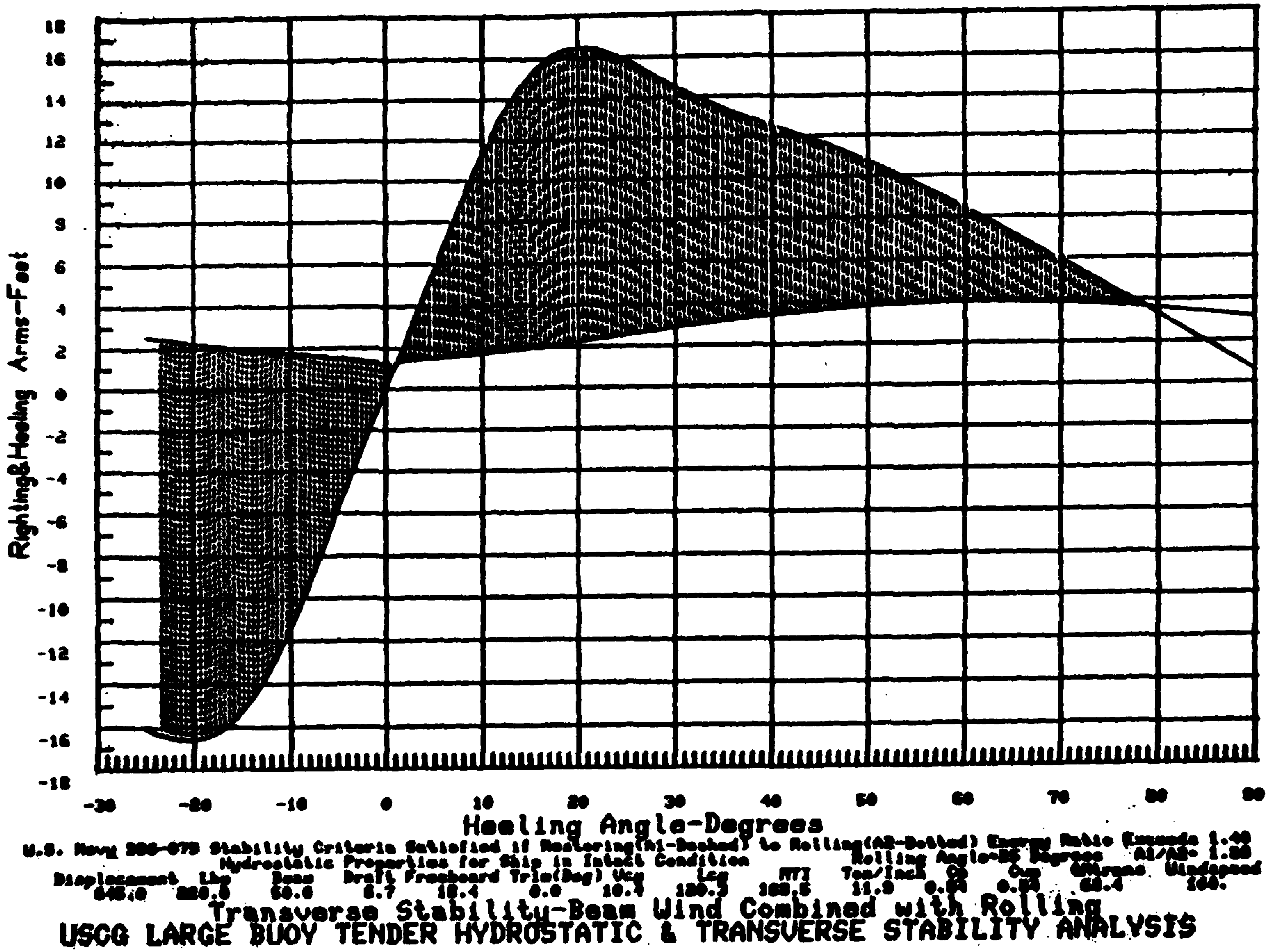


Figure 3.6-16. WLB-SES Intact Stability Wind Heel Burned Out Condition

Calculation of Heeling Angle for

20 Ton Weight Lifted Overside

$GM_{Transverse} = 55.5$ ft.

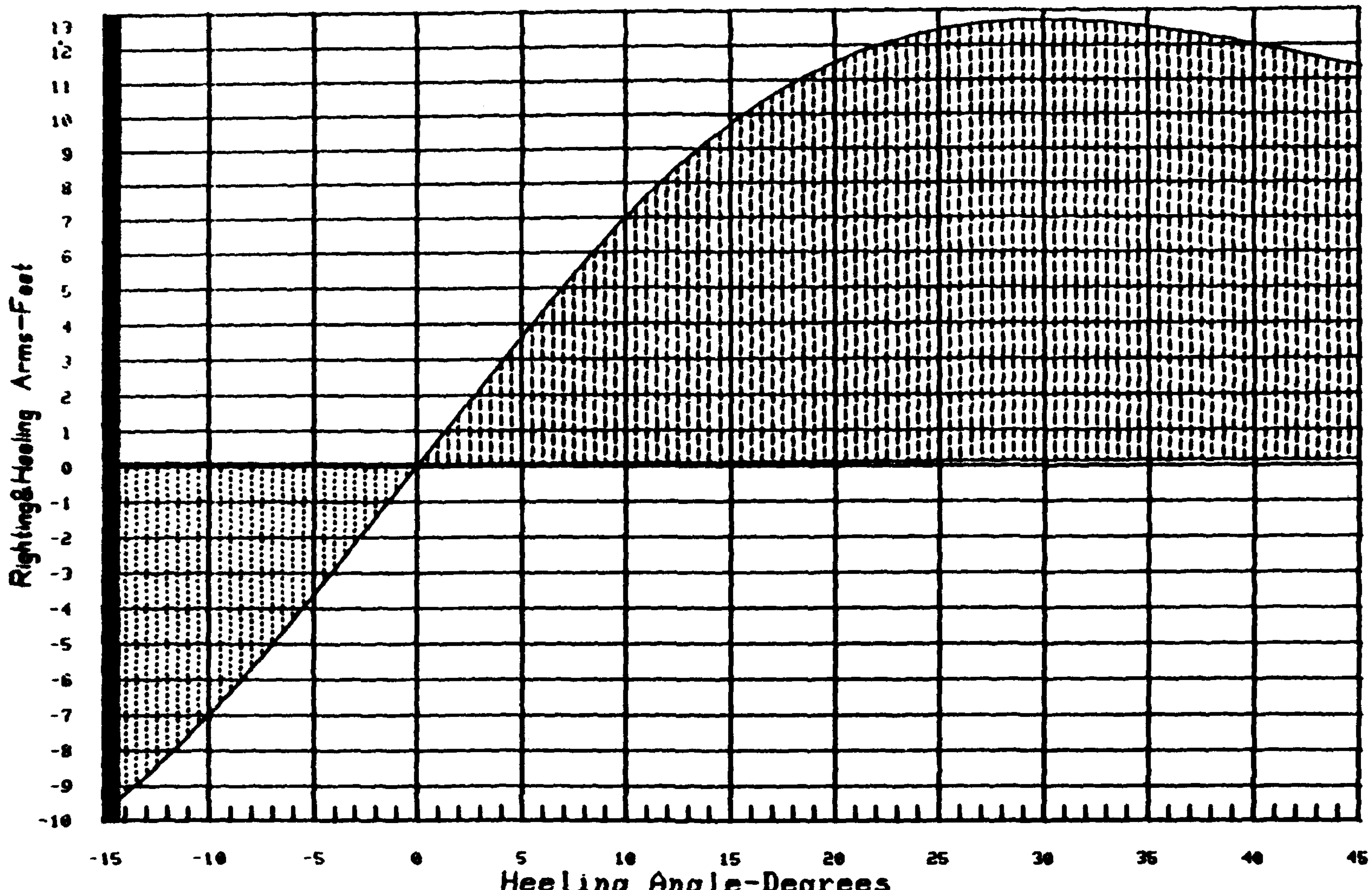
Loss in GM = 1.5 feet (hoisting 20 ton weight)

$GM_{Correctd} = 54$ ft.

Heeling Moment - 20 tons x (15 +½ beam) = 800 ft. -tons

$$\text{Heeling Angle} = \sin^{-1}\left(\frac{800 \text{ ft. tons}}{54 \text{ ft.} \times 800 \text{ ton}}\right) = 1.10 \text{ Degrees}$$

Figure 3.6-17. WLB-SES Intact Stability Heavy Overside Weights

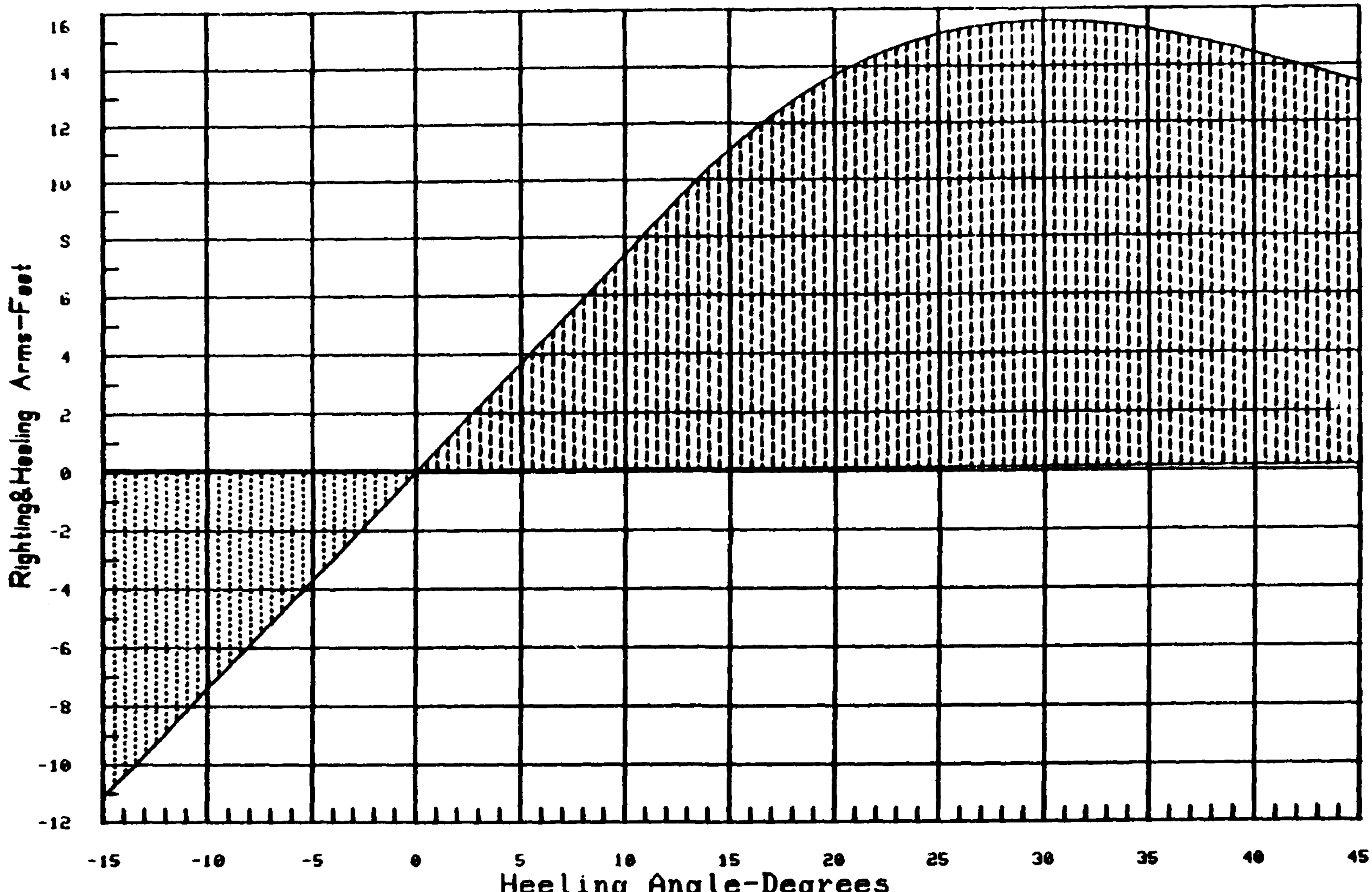


U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 0 and 73 Permeability(Port)-0.95 Permeability(Starboard)-0.95 Rolling Angle-15 Degrees A1/A2- 5.81

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
800.0	220.0	50.0	22.2	14.9	-5.2	9.5	120.3	174.5	12.6	0.84	0.83	55.5	27.

Transverse Stability-Beam Wind Combined with Rolling
USCG LARGE BUOY TENDER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 3.6-18. WLB-SES Damage Stability Compartments 1 and 2, Shell-to-Shell Damage



U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 35 and 114 Permeability(Port)-0.95 Permeability(Starboard)-0.95 Rolling Angle-15 Degrees A1/A2- 6.47

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
800.0	220.0	50.0	14.2	14.9	-1.7	9.5	120.3	174.5	12.6	0.84	0.83	55.5	27.

Transverse Stability-Beam Wind Combined with Rolling
USCG LARGE BUOY TENDER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 3.6-19. WLB-SES Damage Stability Compartments 2 and 3, Shell-to-Shell Damage

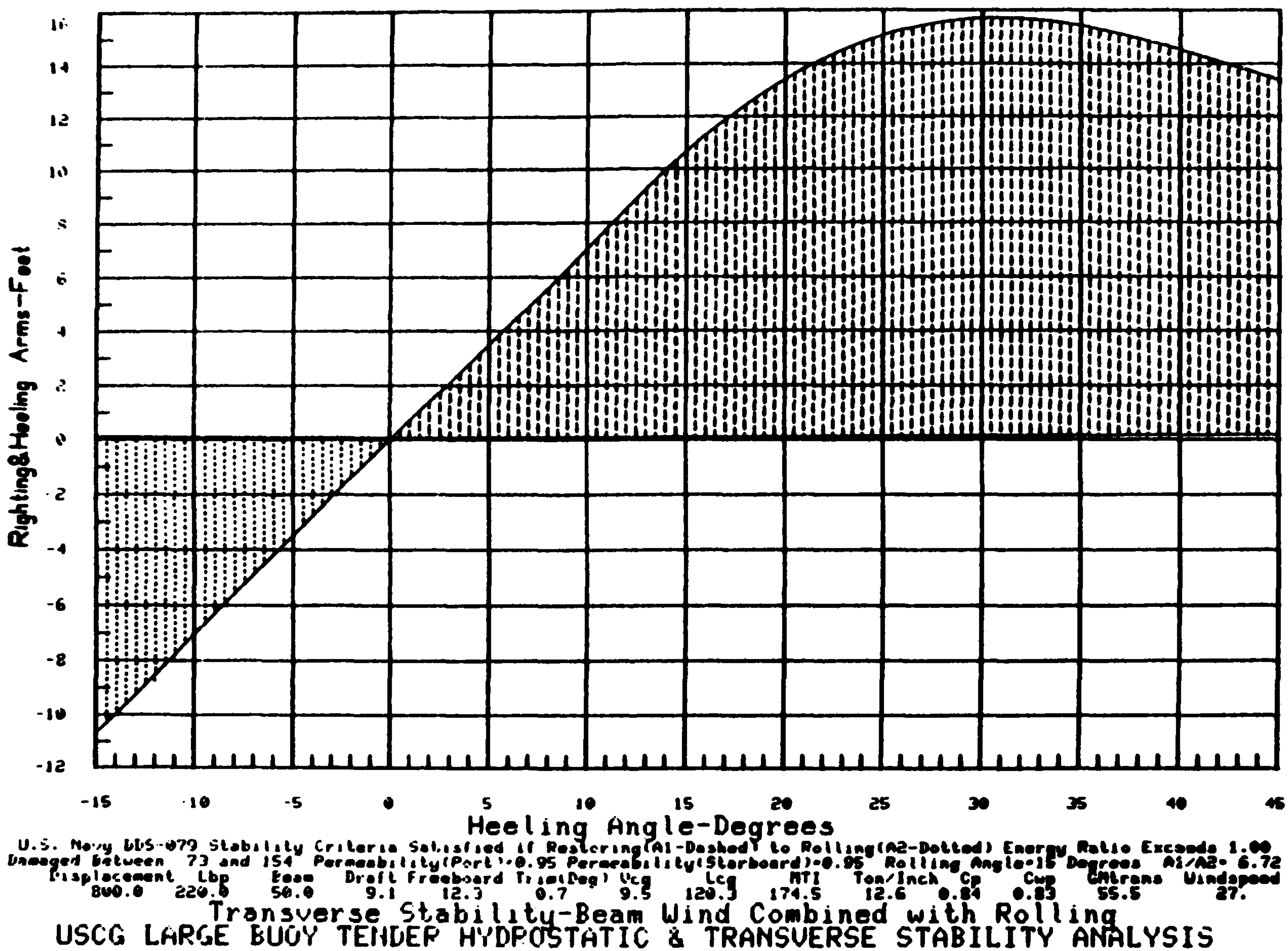


Figure 3.6-20. WLB-SES Damage Stability Compartments 3 and 4, Shell-to-Shell Damage

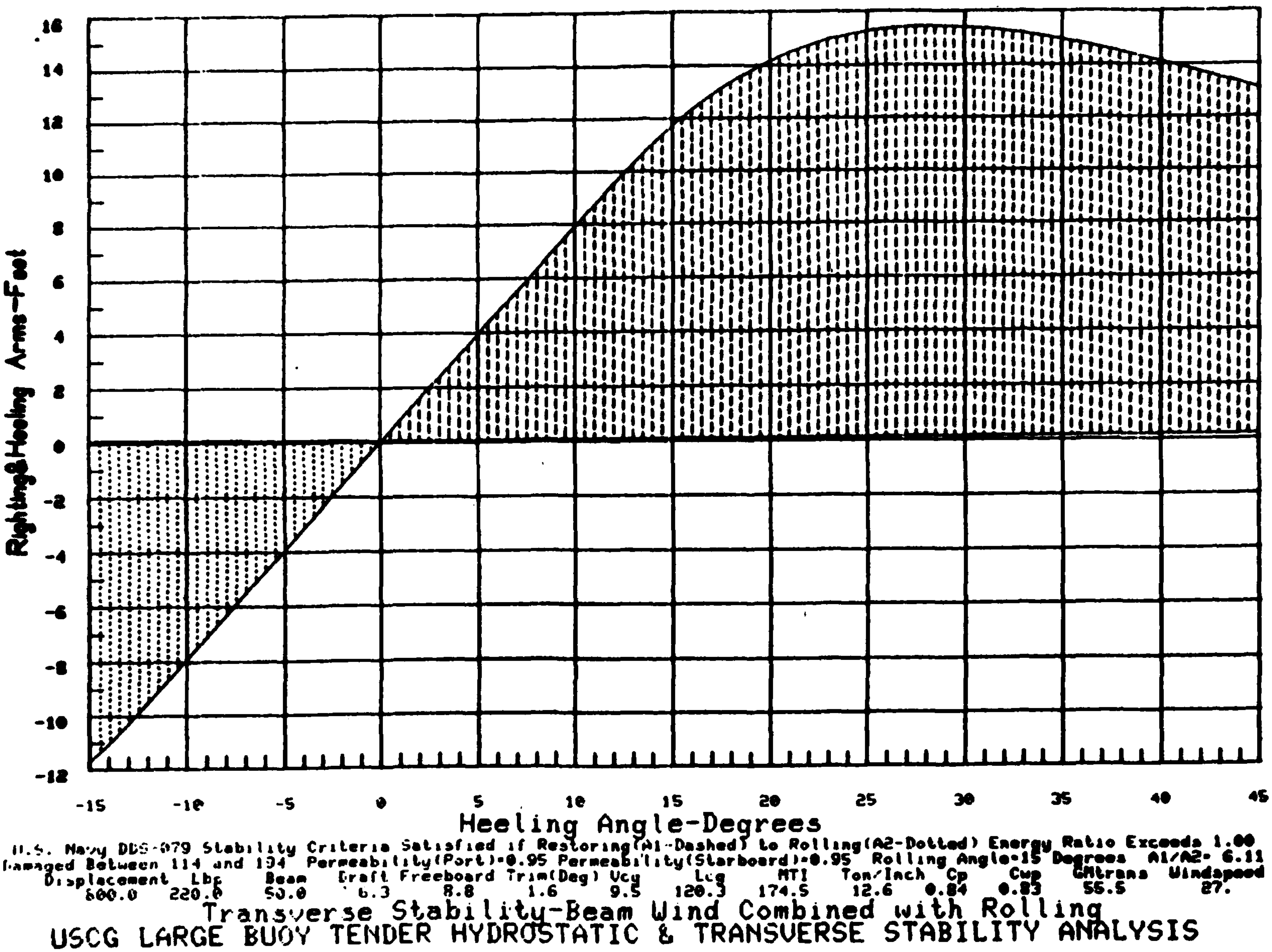


Figure 3.6-21. WLB-SES Damage Stability Compartments 4 and 5, Shell-to-Shell Damage

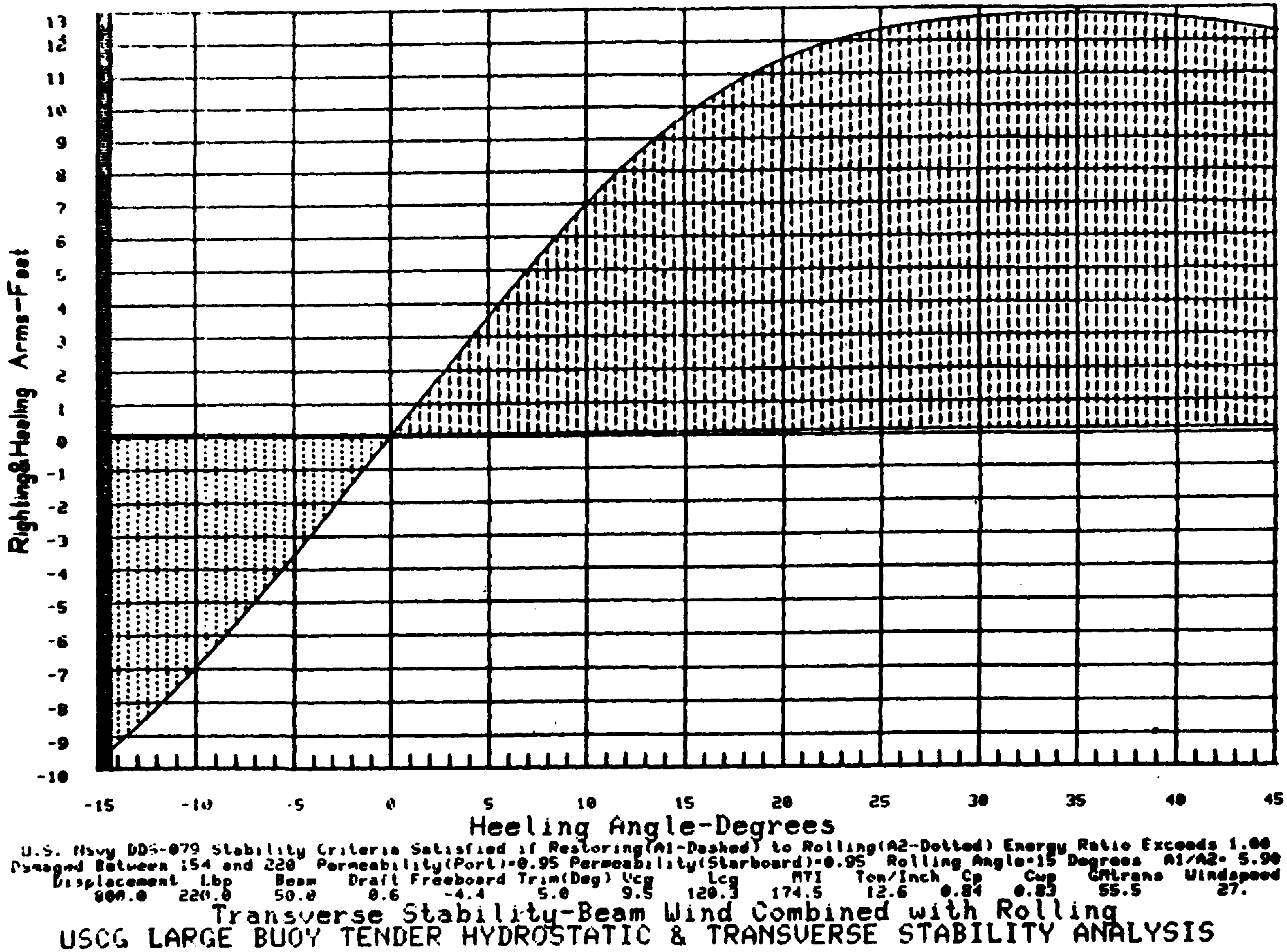
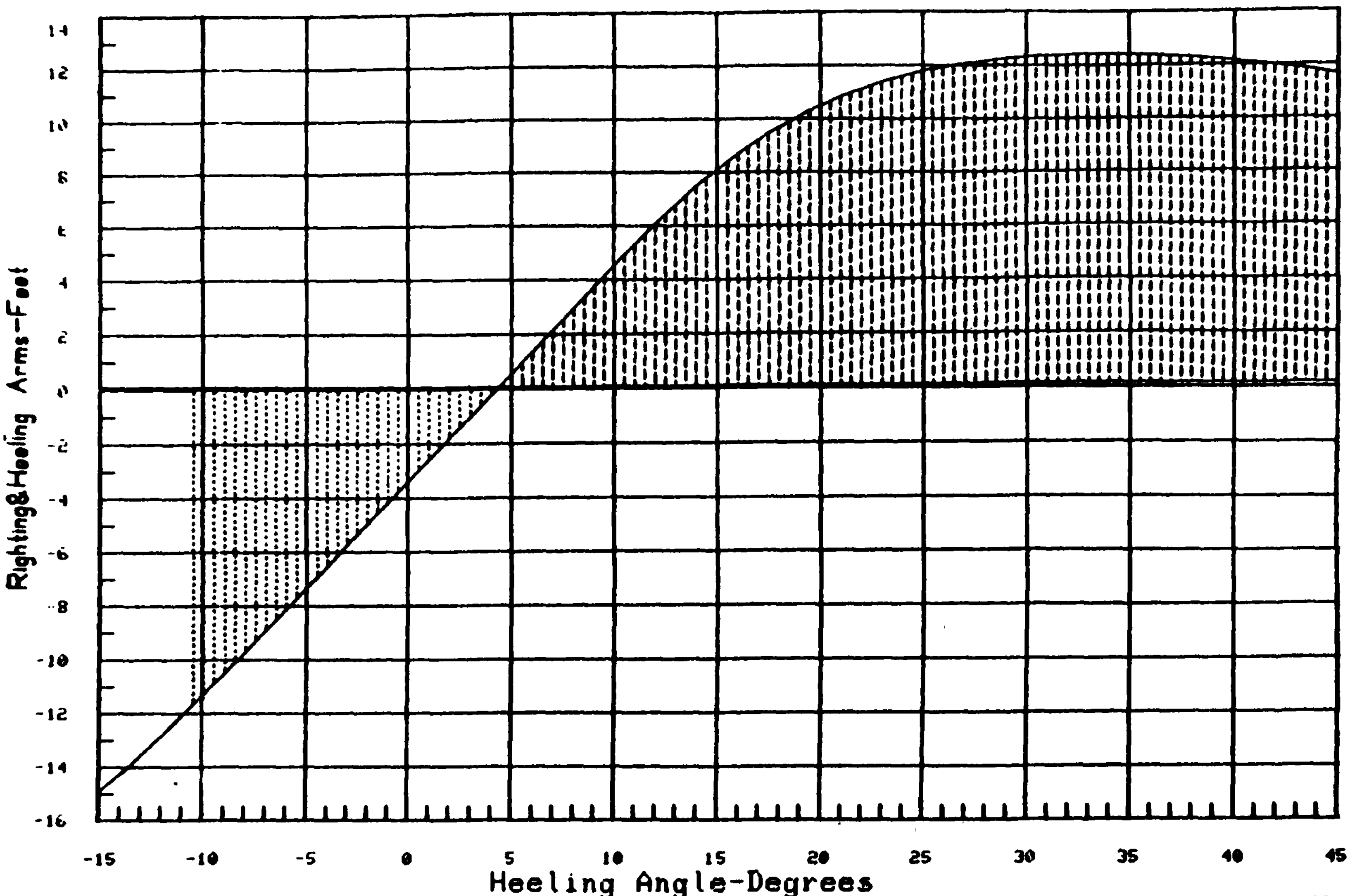


Figure 3.6-22. WLB-SES Damage Stability Compartments 5 and 6, Shell-to-Shell Damage



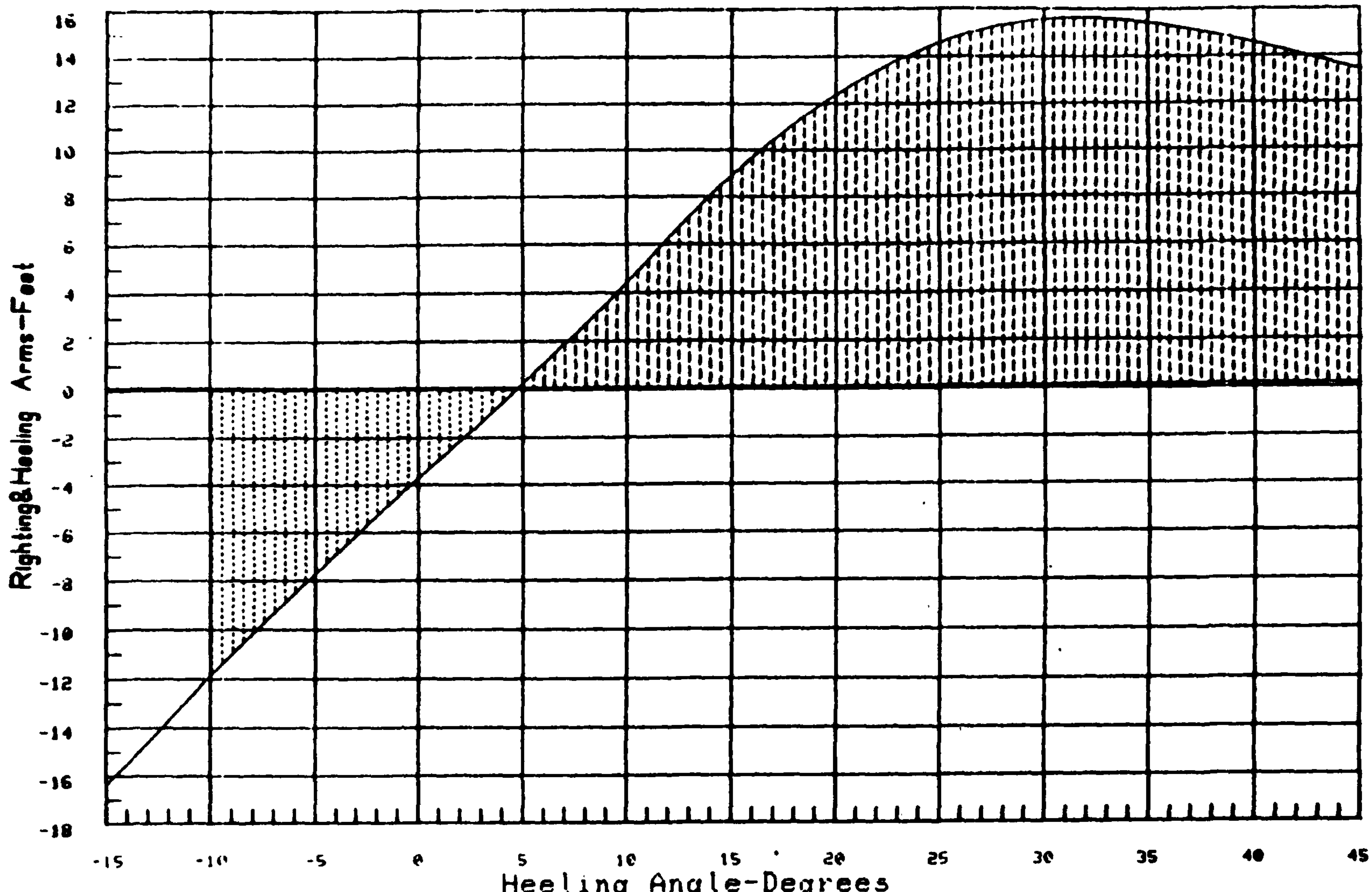
U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 0 and 73 Permeability(Port)-0.00 Permeability(Starboard)-0.95 Rolling Angle-15 Degrees A1/A2- 4.38

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
800.0	220.0	50.0	11.4	18.4	-1.3	9.5	120.3	174.5	12.6	0.84	0.83	55.5	27.

Transverse Stability-Beam Wind Combined with Rolling

USCG LARGE BUOY TENDER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 3.6-23. WLB-SES Damage Stability Compartments 1 and 2, Damage to Centerline

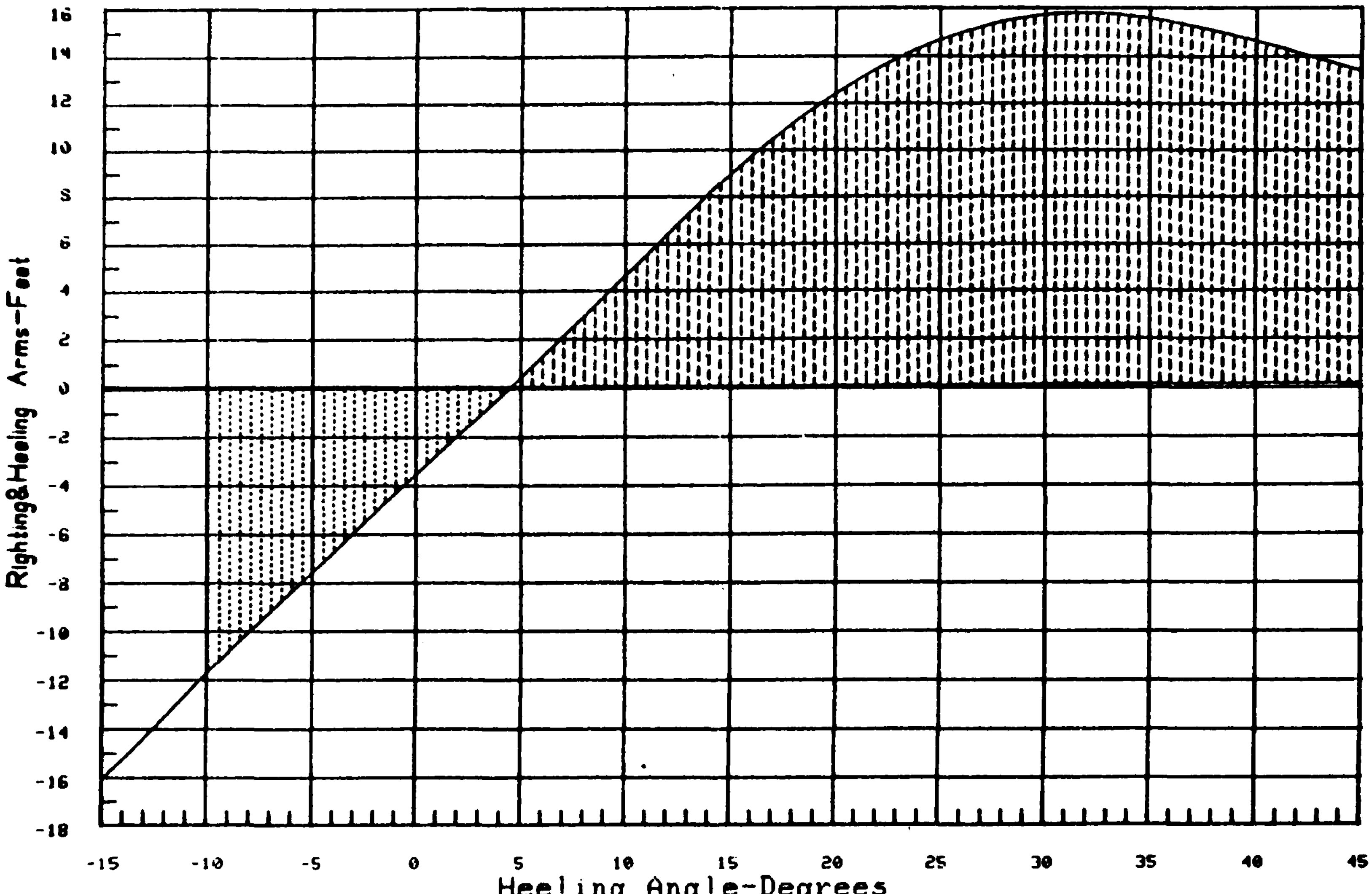


U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 39 and 114 Permeability(Port)=0.00 Permeability(Starboard)=0.95 Rolling Angle=15 Degrees A1/A2= 5.24

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
800.0	220.0	50.0	10.2	13.4	0.6	9.5	120.3	174.5	12.6	0.84	0.83	55.5	27.

Transverse Stability-Beam Wind Combined with Rolling
USCG LARGE BUOY TENDER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 3.6-24. WLB-SES Damage Stability Compartments 2 and 3, Damage to Centerline



U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 73 and 154 Permeability(Port)-0.00 Permeability(Starboard)-0.95 Rolling Angle-15 Degrees A1/A2- 5.46

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
800.0	220.0	50.0	8.3	13.8	0.3	9.5	120.3	174.5	12.6	0.84	0.83	55.5	27.

Transverse Stability-Beam Wind Combined with Rolling
USCG LARGE BUOY TENDER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 3.6-25. WLB-SES Damage Stability Compartments 3 and 4, Damage to Centerline

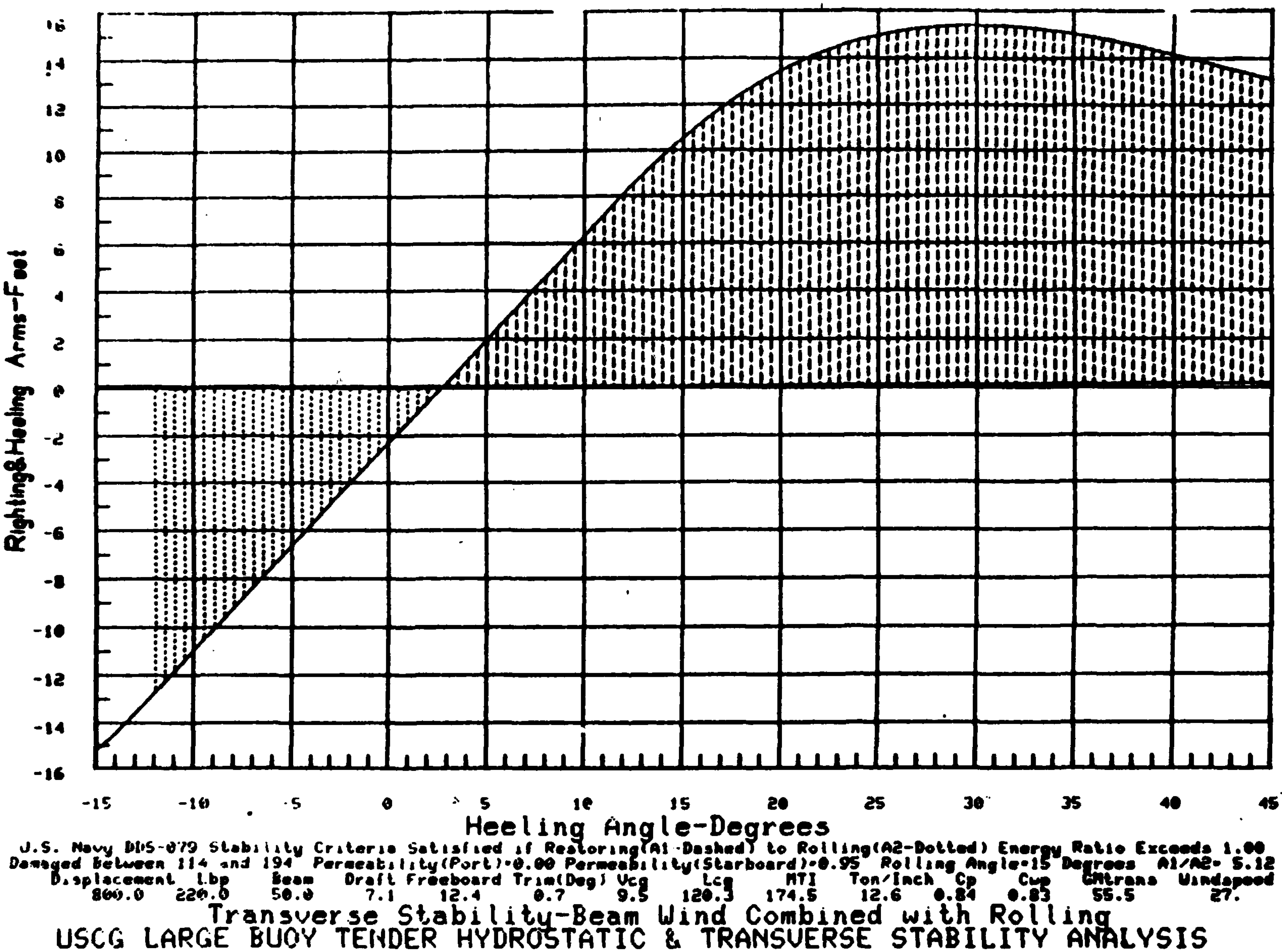
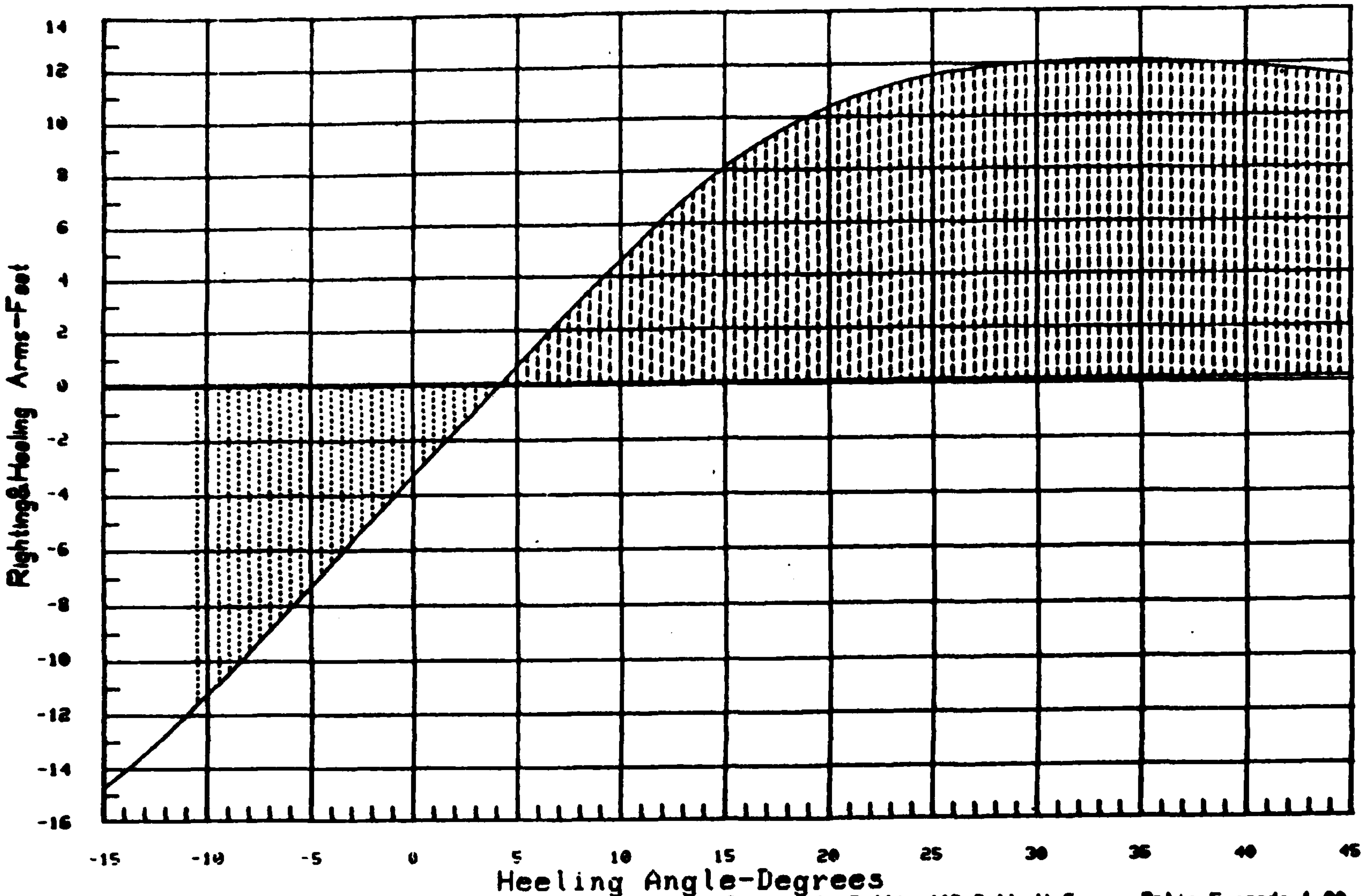


Figure 3.6-26. WLB-SES Damage Stability Compartments 4 and 5, Damage to Centerline



U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 154 and 220 Permeability(Port)=0.00 Permeability(Starboard)=0.95 Rolling Angle=15 Degrees A1/A2= 4.40

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
800.0	220.0	50.0	6.0	9.9	1.3	9.5	120.3	174.5	12.6	0.84	0.83	55.5	27.

Transverse Stability-Beam Wind Combined with Rolling
USCG LARGE BUOY TENDER HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 3.6-27. WLB-SES Damage Stability Compartments 5 and 6, Damage to Centerline

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APPENDIX 4

DESIGN DESCRIPTION - WPC-SES

1. INTRODUCTION

This appendix provides a description of a surface effect ship design concept developed to meet the requirements of the existing USCG - WPC craft. The design concept is described in terms of layout drawings, tables and text.

2. PRINCIPAL CHARACTERISTICS

The principal characteristics of the WPC-SES are summarized in Table 4.2-1.

3. MISSION REQUIREMENTS

The mission requirements are summarized in Table 4.3-1.

4. SHIP CONFIGURATION

The WPC-SES Outboard Profile and Hull Geometry are shown in Figures 4.4-1 and 4.4-2 respectively. The principal features of the control arrangement and major subsystems are discussed in the following paragraphs.

4.1 GENERAL ARRANGEMENT — The general arrangement is shown in Figure 4.4-3. As shown in Figure 4.4-3 all habitability spaces are accommodated on the Second Deck level. Officer accommodations are located forward with direct access to the communication space and pilot house located on the Main Deck and OI Level directly above. Berthing spaces for CPO's and enlisted personnel are located aft. The forward and aft accommodation areas are separated by the enlisted personnel messroom and the single galley area. Longitudinal passageways port and starboard provide unobstructed access for ship operations and damage control. The habitability space deck area allocations

Table 4.2-1. WPC-SES Principal Characteristics

Length Overall	129 Ft - 0 In
Length Cushion	113 Ft - 0 In
Breadth Overall	40 Ft - 0 In
Breadth Cushion	31 Ft - 0 In
Depth Main Deck	17 Ft - 0 In
Depth Cushion	9 Ft - 0 In
Full Load Displacement	250 Long Tons
Cruising Speed (Maximum Continuous Power and SS 2)	30 Knots
Propulsion Machinery	Two SACM 12V195RVR Diesel Engines
Propellers	Two Propellers
Lift Engines	Two WM400T Diesel Engines
Lift Fans	Four Mixed Flow

Accommodations:

	Permanent Crew
Officers	2
CPO's	3
Enlisted Personnel	19
Total	24

Table 4.3-1. WPC Design Requirements

A. Missions:

ELT - Enforcement of Laws & Treaties	SRA - Short Range Aids to Navigation
SAR - Search and Rescue	MER - Marine Environmental Response
MP - Military Preparedness	

B. Mission Equipment:

Stores (3.0 Ltons)	6M RHI w/single prop diesel (3.3 Ltons-19'x8'x4')
Water (3.0 Ltons)	2-50 cal. M60 w/mounts & ammo (.5 Ltons)
Crew (4.7 Ltons)	Towline (.5 Ltons-3'x3'x3')
C3 and navigation (4.0 Ltons)	Towing bitt (.3 Ltons-1'x3'x3')
30mm w/ammo & GFCS (5.0 Ltons)	Small arms locker (.1 Ltons-6'x2'x3')
Safe (.3 Ltons-3'x4'x3')	Desalinator (SW-600) (.1 Ltons- 4'x2'x2')
3 - P60 pumps (.5 Ltons)	Pyro locker (.1 Ltons-3'x4'x5')

C. Speed vs. Sea State:

30 kts/SS2	35 kt dash capability (calm water)
25 kts/SS3	
20 kts/SS4	

D. Endurance:

7 days (168 hrs.)	24 hrs @ a speed of 30 kts
	144 hrs @ cruise speed (12 kts)
	10% reserve fuel

E. N/A - to be governed by (D.)

F. Operating Environment:

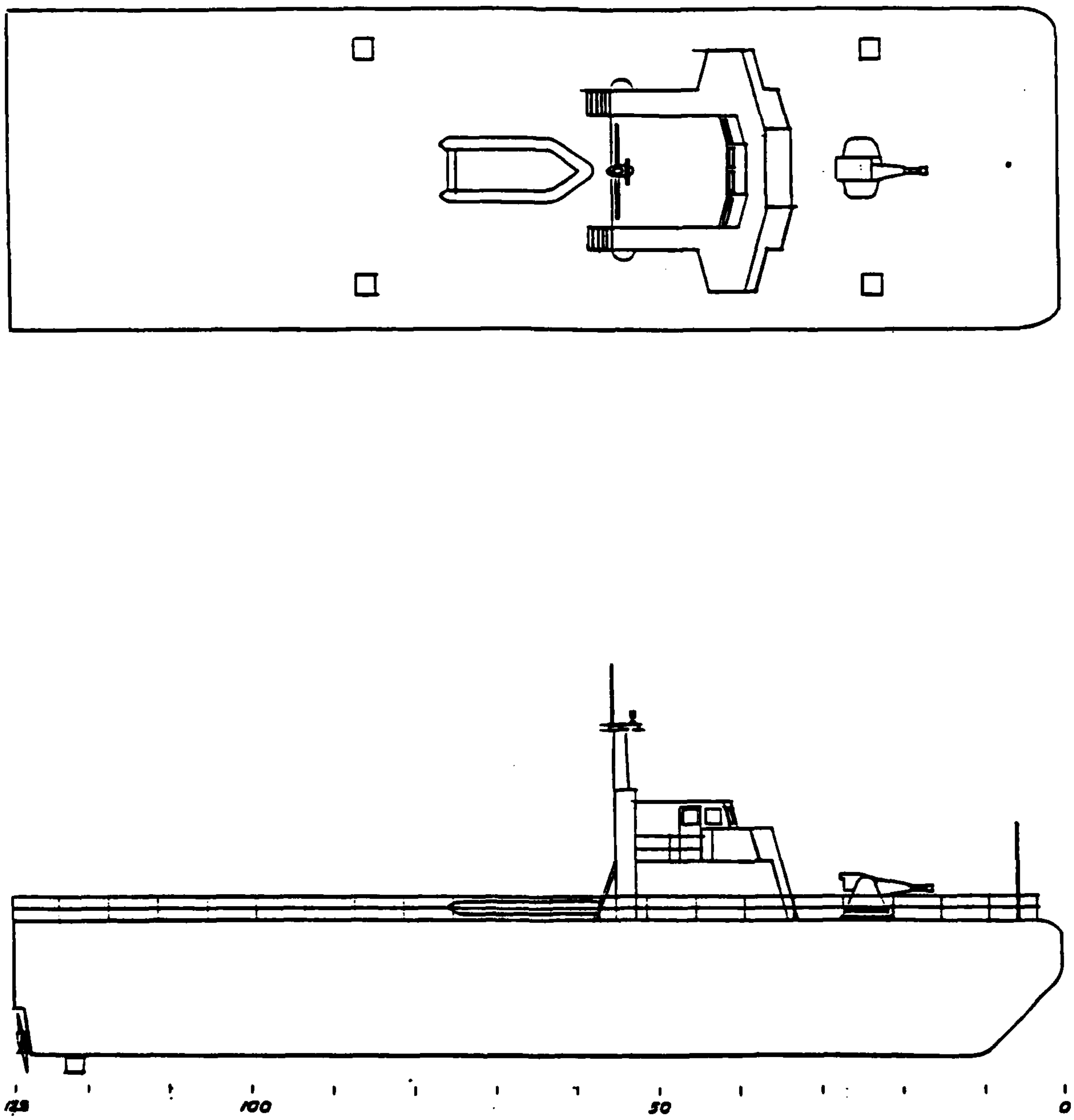
Be able to operate 90% of the time in U.S. coastal waters south of 38N within 300 miles of land (no ice capability)

G. Complement:

24 Permanent Crew	2-Officers
	3-CPOs
	19-Enlisted

H. Other Design Features:

1. Available ride control system for improving ride quality
2. USN 2 compartment intact and damage stability
3. External fire fighting capability (125 psi)


125
100
50
0

2

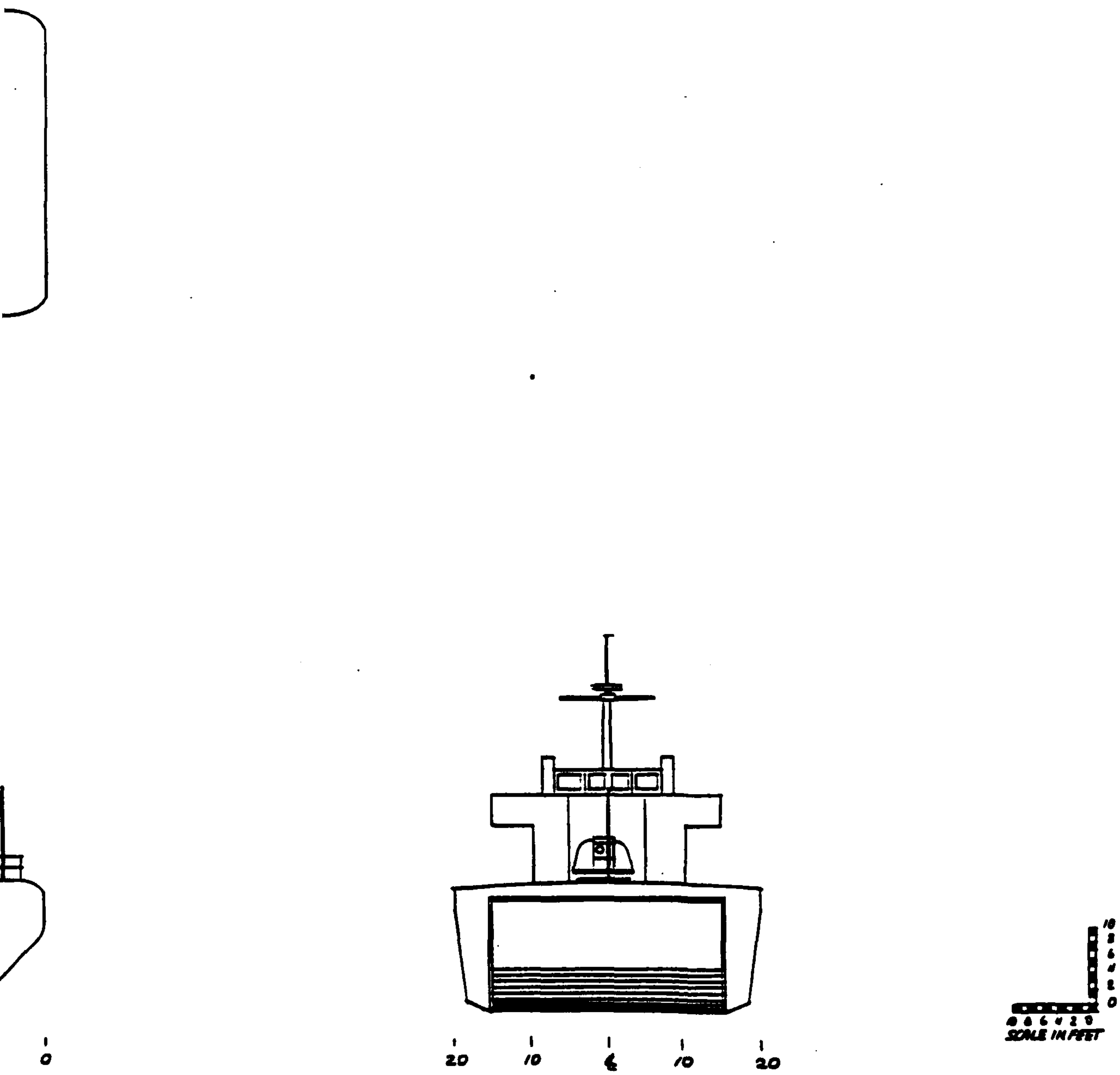
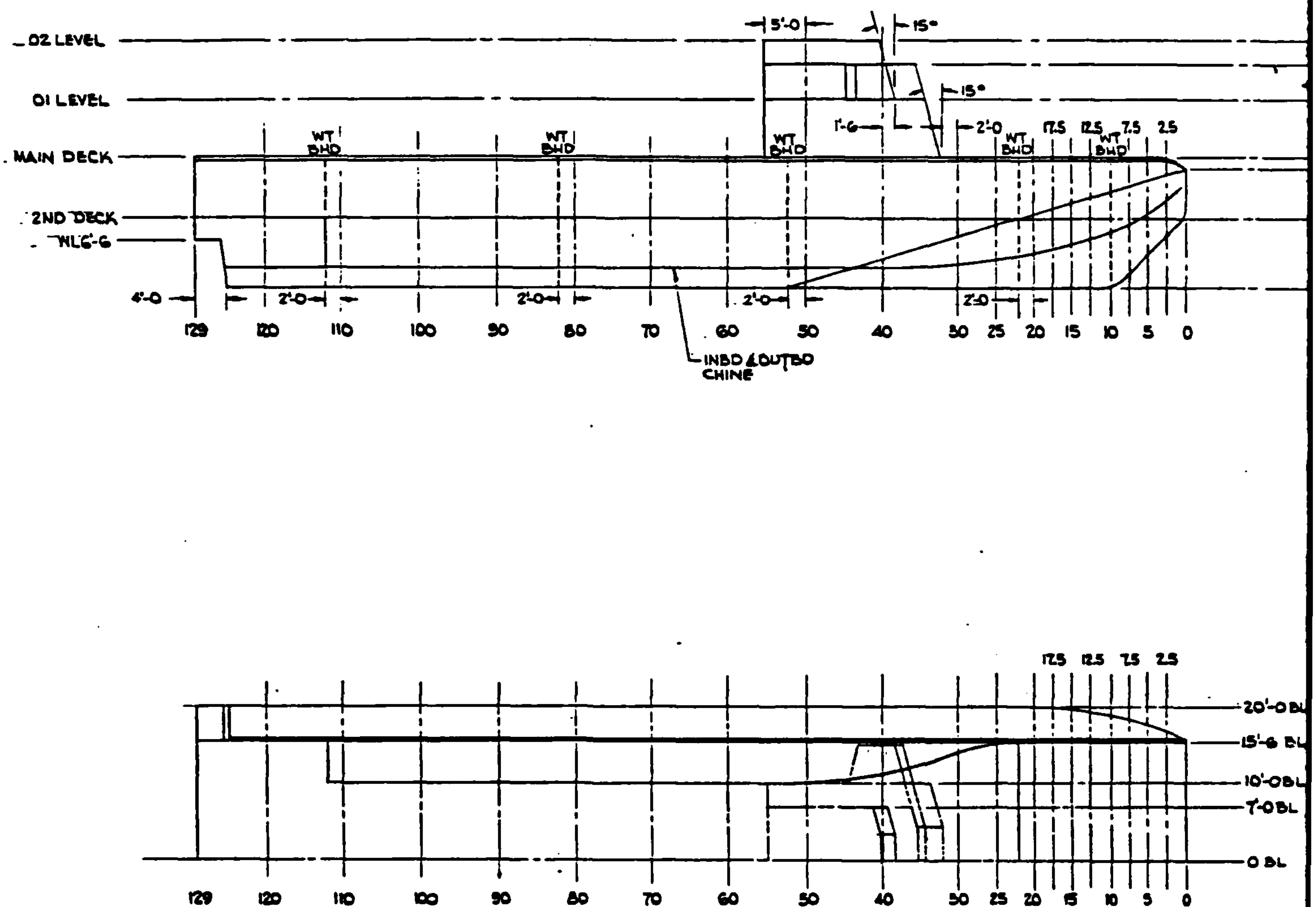
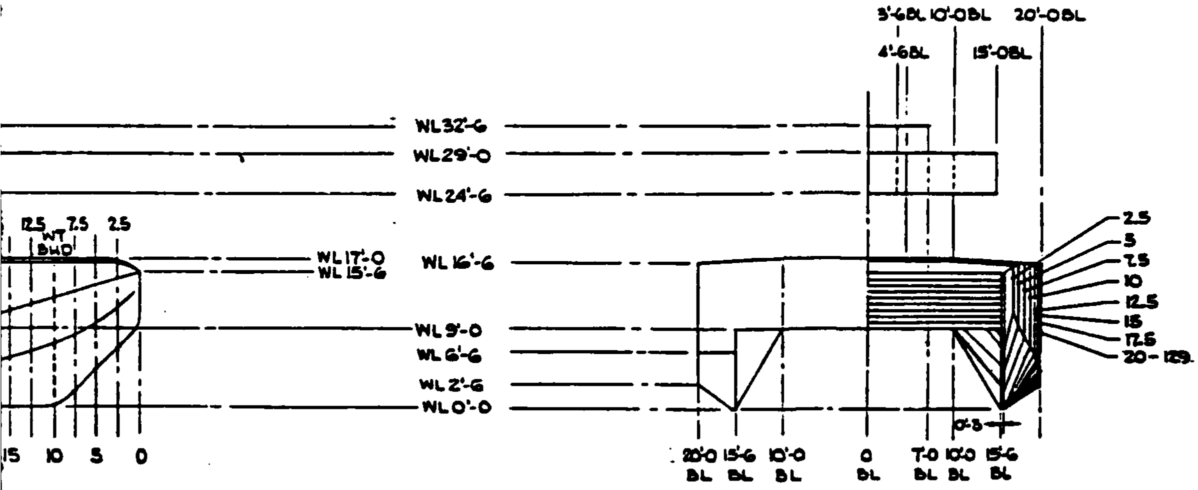
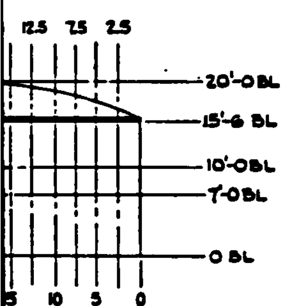


Figure 4.4-1
WPC-SES
Outboard Profile



02 LEVEL
01 LEVEL
MAIN DECK
2ND DECK
WL 6'-6
5'-0
15°
15°
1'-6
2'-0
WT BHD
WT BHD
WT BHD
WT BHD
WT BHD
17.5 12.5 7.5 2.5
4'-0
2'-0
2'-0
2'-0
2'-0
129 120 110 100 90 80 70 60 50 40 30 25 20 15 10 5 0
INBD & OUTBD CHINE
17.5 12.5 7.5 2.5
20'-0 BL
15'-6 BL
10'-0 BL
7'-0 BL
0 BL
129 120 110 100 90 80 70 60 50 40 30 25 20 15 10 5 0





PRINCIPAL PARTICULARS

LENGTH OVERALL	129'-0
BEAM OVERALL	40'-0
CUSHION LENGTH	115'-0
CUSHION BEAM	31'-0
CUSHION DEPTH	9'-0
DEPTH TO MAIN DECK	17'-0
DESIGN DISPLACEMENT	250 L TONS
DRAFT HULLBORNE	5'-6

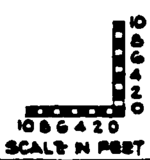
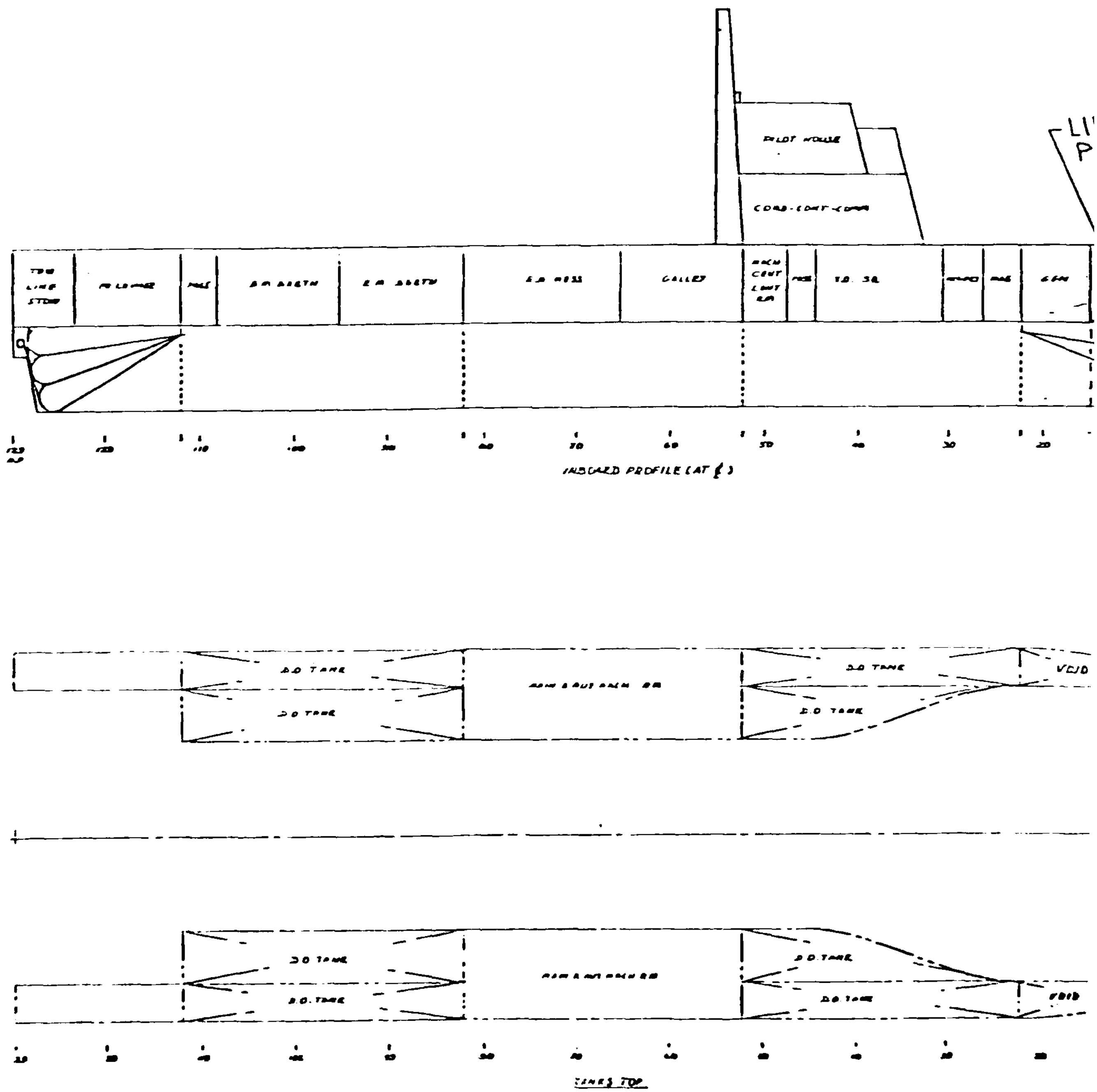
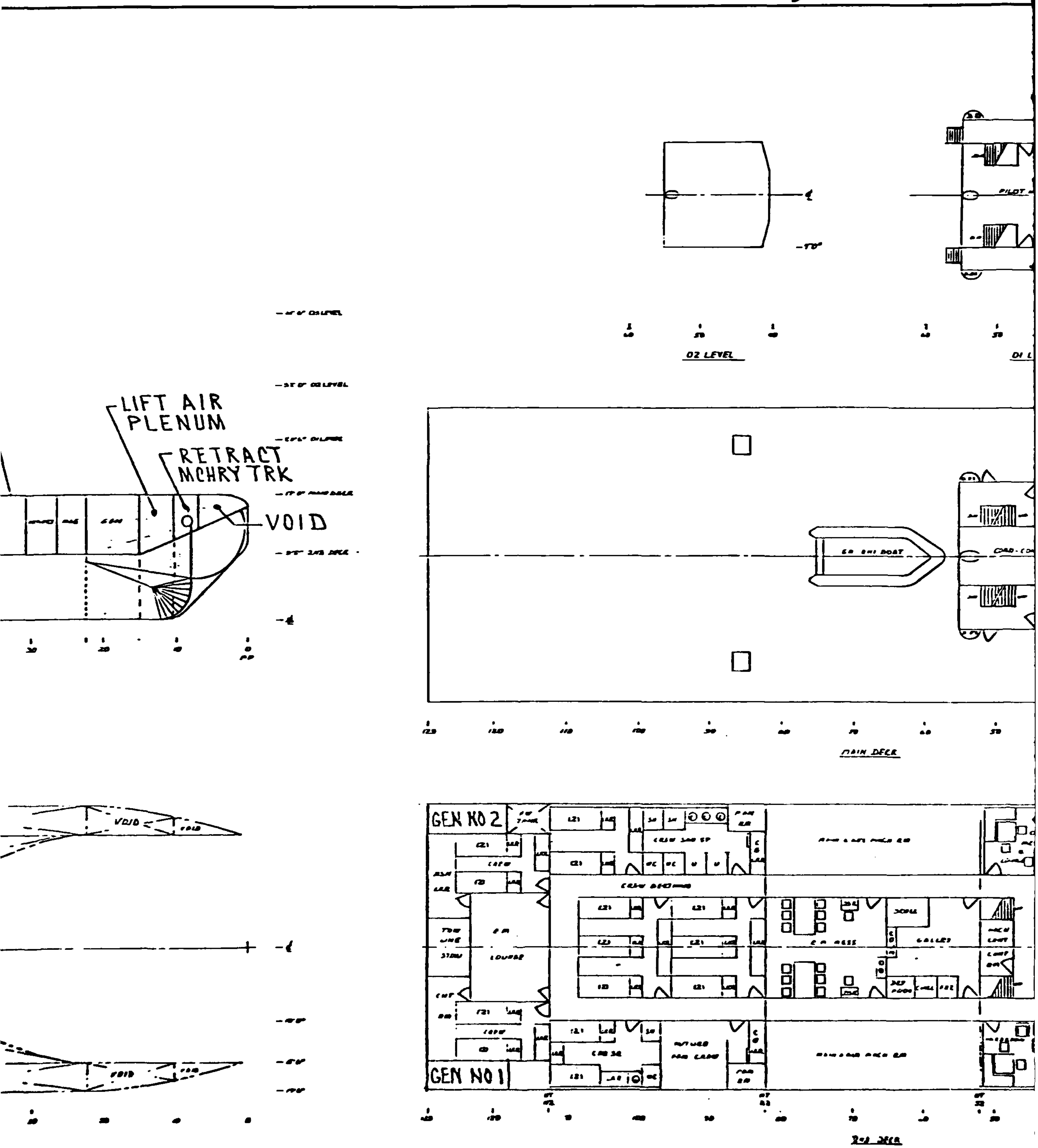


Figure 4.4-2. WPC-SES Hull Lines



PILOT HOUSE
GALLEY
E.M. BERTH
D.O. TANK
D.O. TANK
D.O. TANK
D.O. TANK
D.O. TANK
D.O. TANK
D.O. TANK
D.O. TANK
INBOARD PROFILE (AT ℄)
TANKS TOP



LIFT AIR PLENUM
RETRACT MCHRY TRK
VOID
02 LEVEL
MAIN DECK
GEN NO 2
GEN NO 1
CREW BERTHING
LOUNGE
GALLEY

3

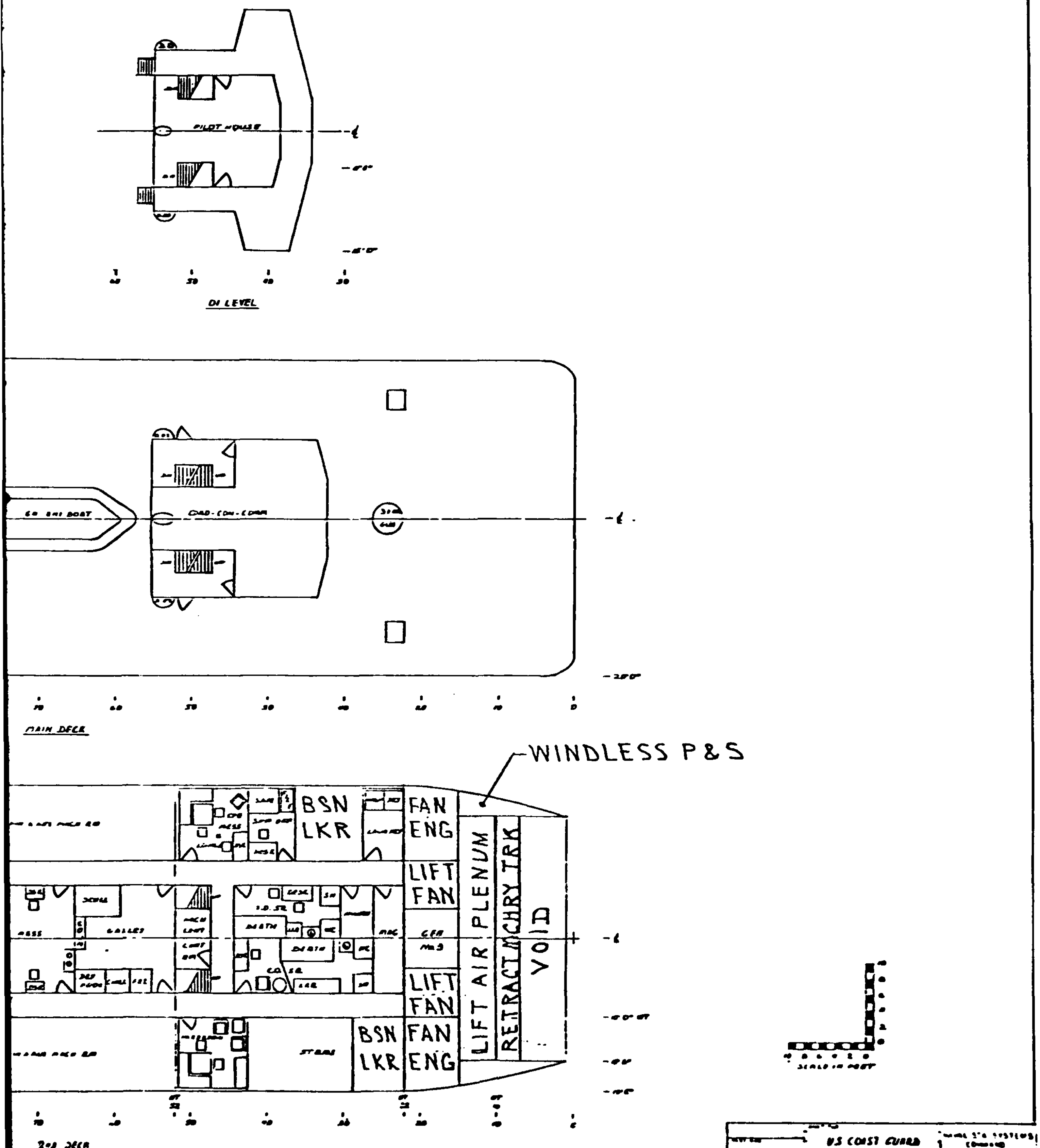


Figure 4.4-3. 129 Ft WPC-SES Patrol Craft General Arrangement

and other hull volume allocations are summarized in Table 4.4-1. For comparison, the habitibility space deck area allocations provided in the existing 95 foot WPB class ship are also shown in Table 4.4-1.

4.2 HULL STRUCTURE -- The hull is constructed of all welded high strength, 500 series, marine grade aluminum alloy. The structural arrangement is shown in Figure 4.4-4. The structural design criteria and the shear and bending moment envelope derived for the structural design are shown in Figures 4.4-5 and 4.4-6 respectively.

4.3 MACHINERY ARRANGEMENT -- The arrangement of the propulsion and lift machinery is shown in figure 4.4-7. As shown in Figure 4.4-7 the propulsion engines, aft lift engines and aft lift fans are located port and starboard in the sidehull regions amidship. The forward lift engines and fans are located on the forward region of the Second Deck. The arrangement shown was selected to provide the maximum isolation of the machinery from habitability spaces within the constraints of ship size and other arrangement requirements. The machinery isolation provided by the arrangement coupled with the installation of vibration isolation mounts for all machinery and accoustical treatment on machinery space boundaries should ensure low levels of noise and vibration in all habitability spaces.

The cushion seal installation consists of a transversely stiffened membrane (TSM) bow seal and a multiple loop bag stern seal. Both bow and stern seal are shown in Figures 4.4-8 and 4.4-9 respectively. The seal materials are listed in Table 4.4-2.

4.4 ELECTRICAL SYSTEM -- The electrical power system consists of three 50KW, 60Hz diesel generators connected in a ring bus distribution system. The power provided by the two operating diesel engines is adequate to satisfy the ship's electrical power requirements under all operating conditions. The third generator provides standby power. Transformer rectifiers of a type proven in service aboard Navy ships are used to provide 28 volt DC for control and actuator power, as required. A battery bank is used to provide

Table 4.4-1. WPC-SES - Deck Area and Hull Volume Allocations

SPACE DESCRIPTION		WPC-SES		EXISTING CRAFT			
				95 FT WPB			
		FT²	FT²/MAN	FT²	FT²/MAN	FT²	FT²/MAN
BERTHING	CO	105	105	69	69		
	Officer	81	81	-	-		
	CPO	120	40	42	14		
	EM	670	35.3	234	12.3		
SANITARY	CO	17.5					
	Officer	17.5		20.5			
	CPO	225					
	EM	114		70.5			
MESS	Ward Room	80					
	CPO Mess	80		132			
	EM Mess	238					
	EM Lounge	165		-			
COMMISSARY	Galley	122					
	Scullery	26					
	Chill	9		77			
	Freeze	9					
	Dry Food	12					
	Laundry	50		-			
	TOTAL	2141		645			

Table 4.4-1. WPC-SES - Deck Area and Hull Volume Allocations (Cont'd.)

SPACE DESCRIPTION		WPC-SES		EXISTING CRAFT			
				95 FT WPB			
		FT^2	FT^2/MAN	FT^2	FT^2/MAN	FT^2	FT^2/MAN
	Pilothouse	201		68			
	Command, Control and Communication	332		64			
	Magazine	56		-			
	Armory	28		-			
	Central Control Station	34		-			
	BSN Lkr.	203		74			
	CHT System	53		42			
	Ship Office	54		-			
	Storeroom	195		39			
	Mach. and Auxiliary	692		360			
	Third Generator	185		66			
	TOTAL	2033		713			
	Unassigned	288.6					

OTHER EQUIPMENT:

Water

Required 3 Tons

Available = 5.2 x .95 x .98 = 5.1 Tons

Fuel

Required* = 41. + 9.4 = 50.4 Tons

Available

Tank (1 & 2) = 35.3 x .95 x .98 = 32.9 Tons

Tank (3 & 4) = 19.1 x .95 x .98 = 17.8 Tons

Tank (5, 6, 7 & 8) = 70.6 x .95 x .98 = 65.7 Tons

TOTAL 116.4 Tons

*The values given are ship and helo fuel estimates (Table 4.2-4.)

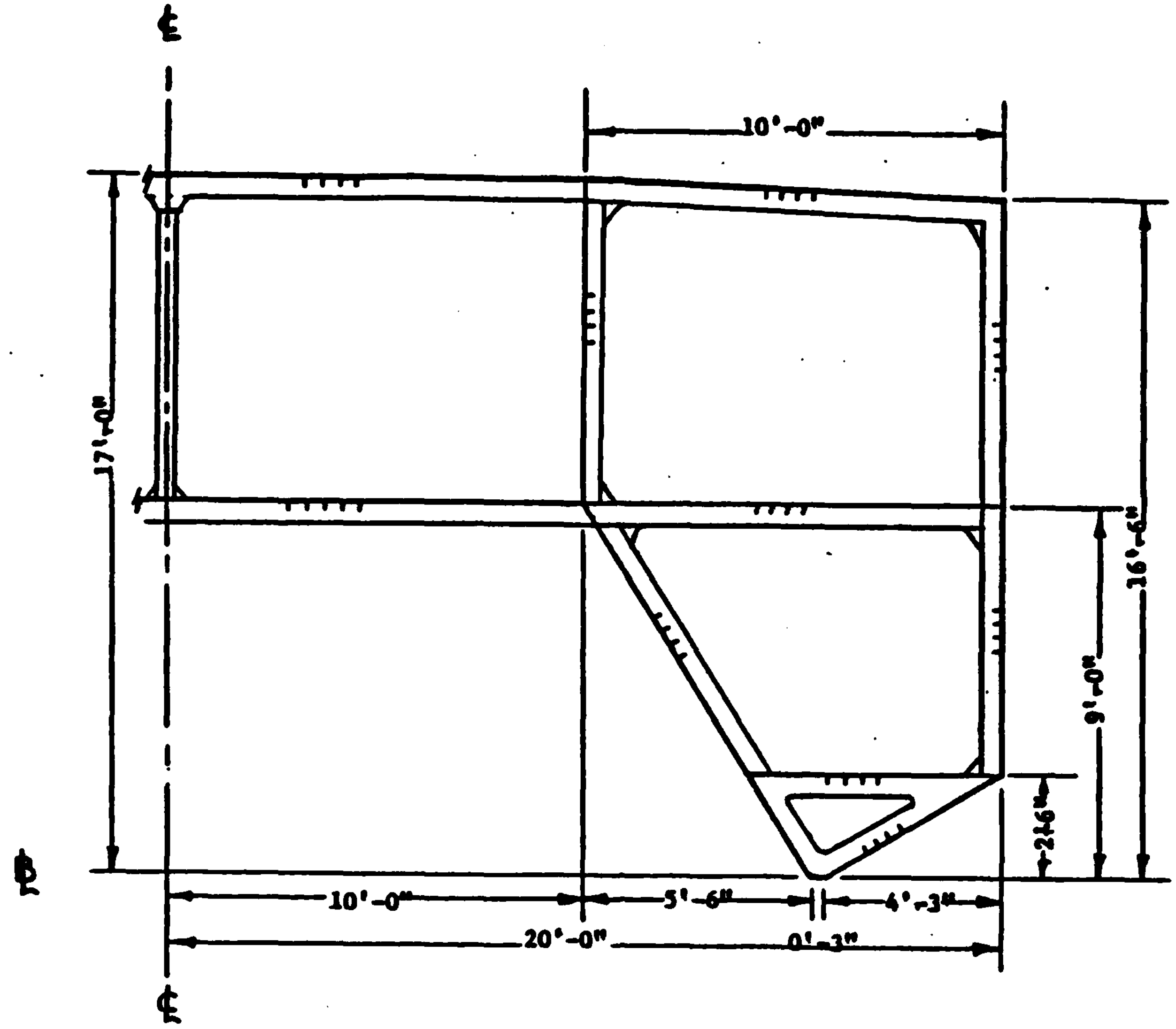


Figure 4.4-4. Midship Section - WPC-SES

SLAM PRESSURES ARE NOT COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS (OTHER THAN SLAMMING) ARE COMBINED WITH HULL GIRDER LOADS

LOCAL LOADS INCLUDE DECK
LIVE LOADS: 75 PSF (TOP OF DK HSE)
150 PSF (LIVING, OFFICE SPACES)
200 PSF (MACHINERY SPACES)

USE 50% OF SLAM PRESSURE FOR FRAME DESIGN

SAFETY FACTORS	YIELD	ULT.
HULLBORNE + LOCAL LOADS	1.2	1.5
CUSHIONBORNE + LOCAL LOADS	1.2	1.5
SLAMMING PRESSURES	1.0	1.2

PERMANENT SET TO A MAXIMUM OF PLATE THICKNESS IS ALLOWED

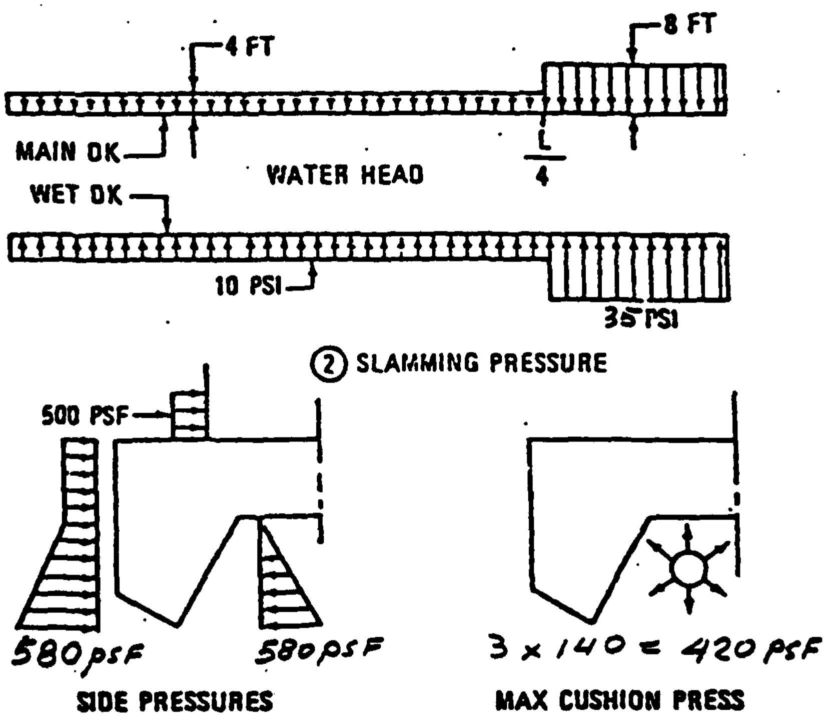
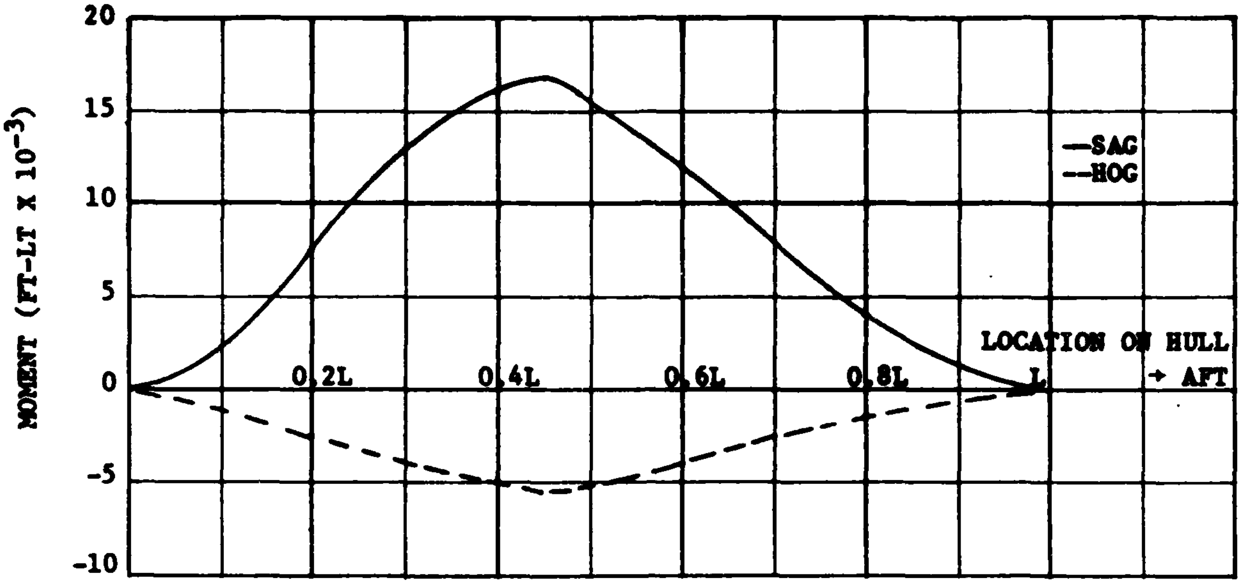
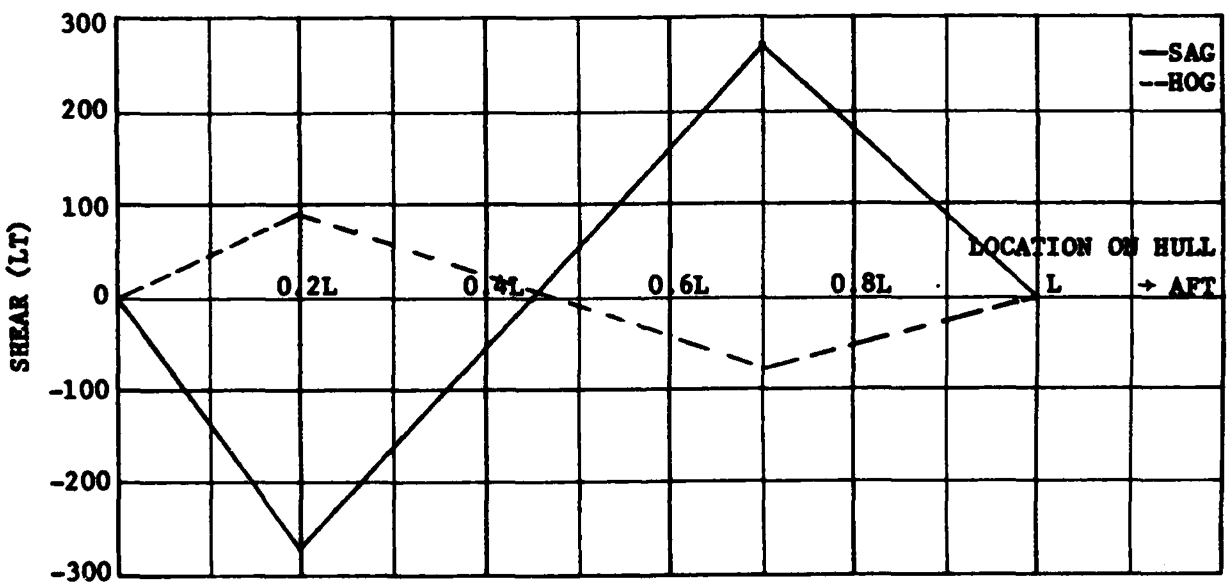


Figure 4.4-5. WPC-SES Hull Design Criteria



HULLBORNE BENDING MOMENT



HULLBORNE SHEAR

Safety Factor - SF Yield = 1.2
SF ULT = 1.5

Figure 4.4-6. WPC-SES Design Shear and Bending Moment Envelopes

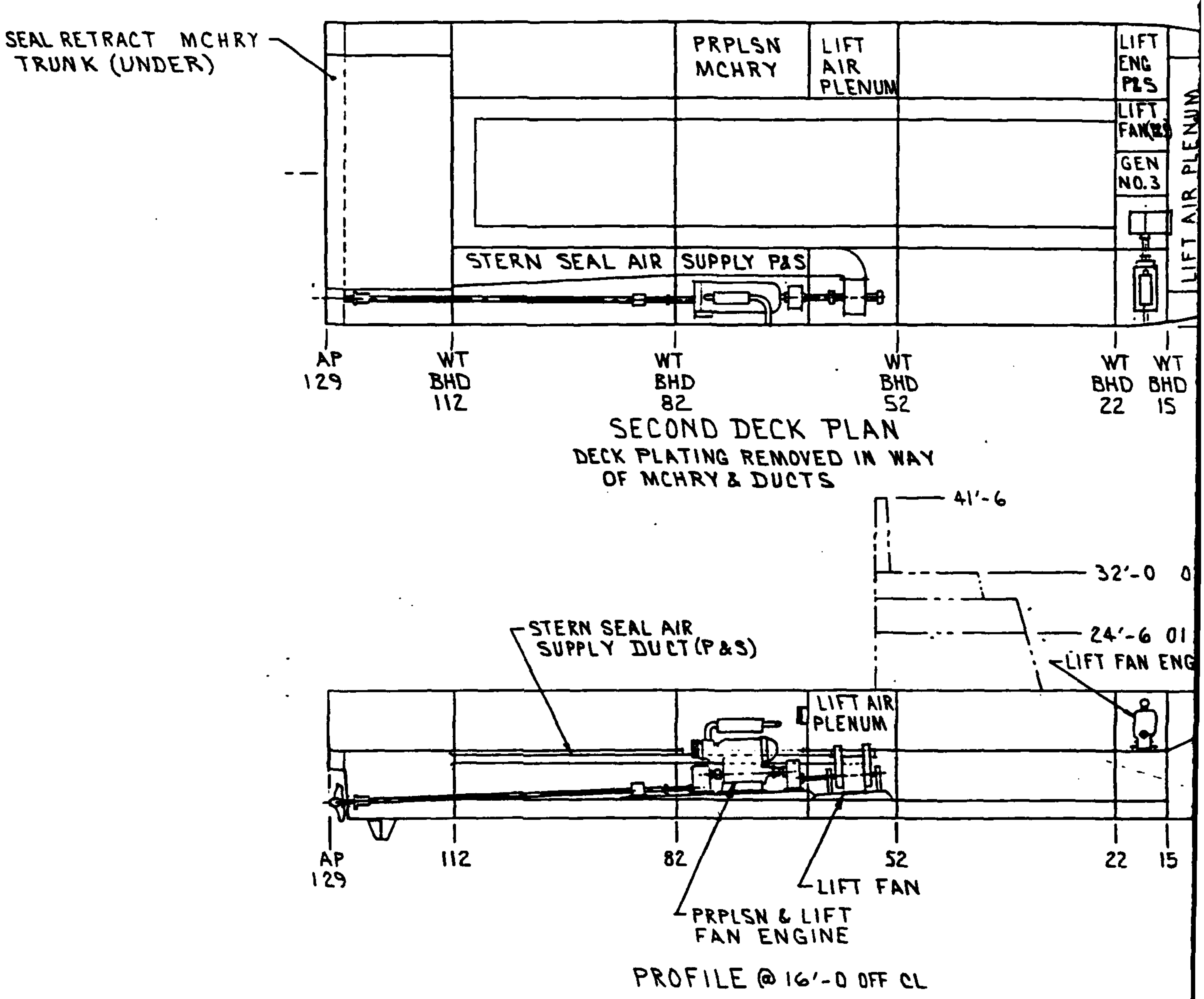


Figure 4.4-7. WPC-SES Mach

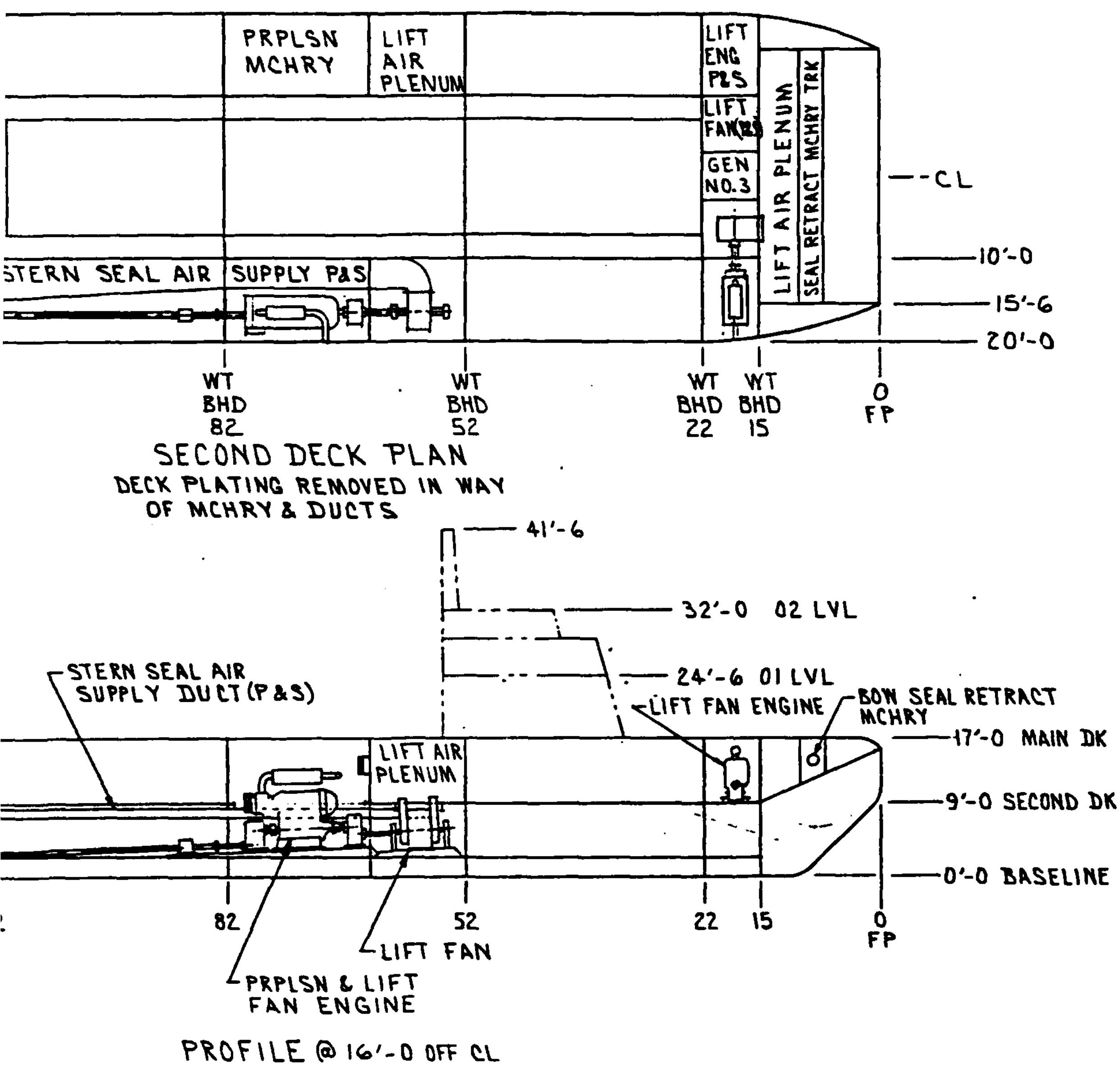


Figure 4.4-7. WPC-SES Machinery Arrangement

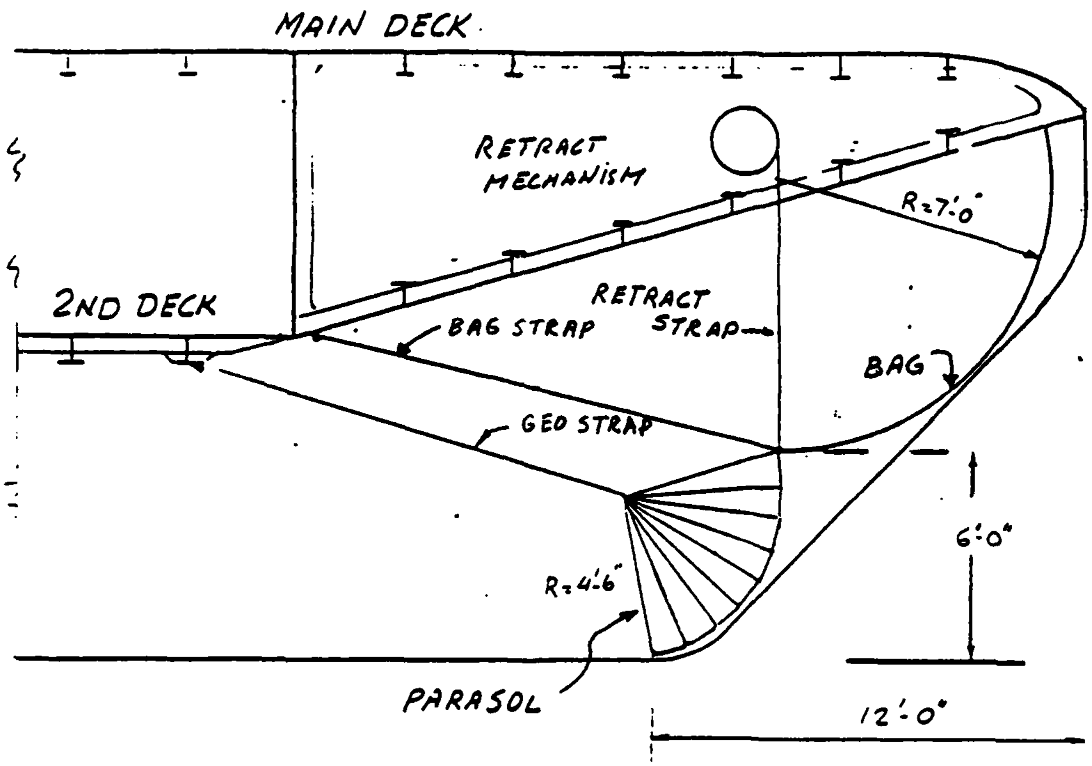


Figure 4.4-8. WPC-SES Bow Seal Schematic (Transversely Supported Membrane (TSM) Seal)

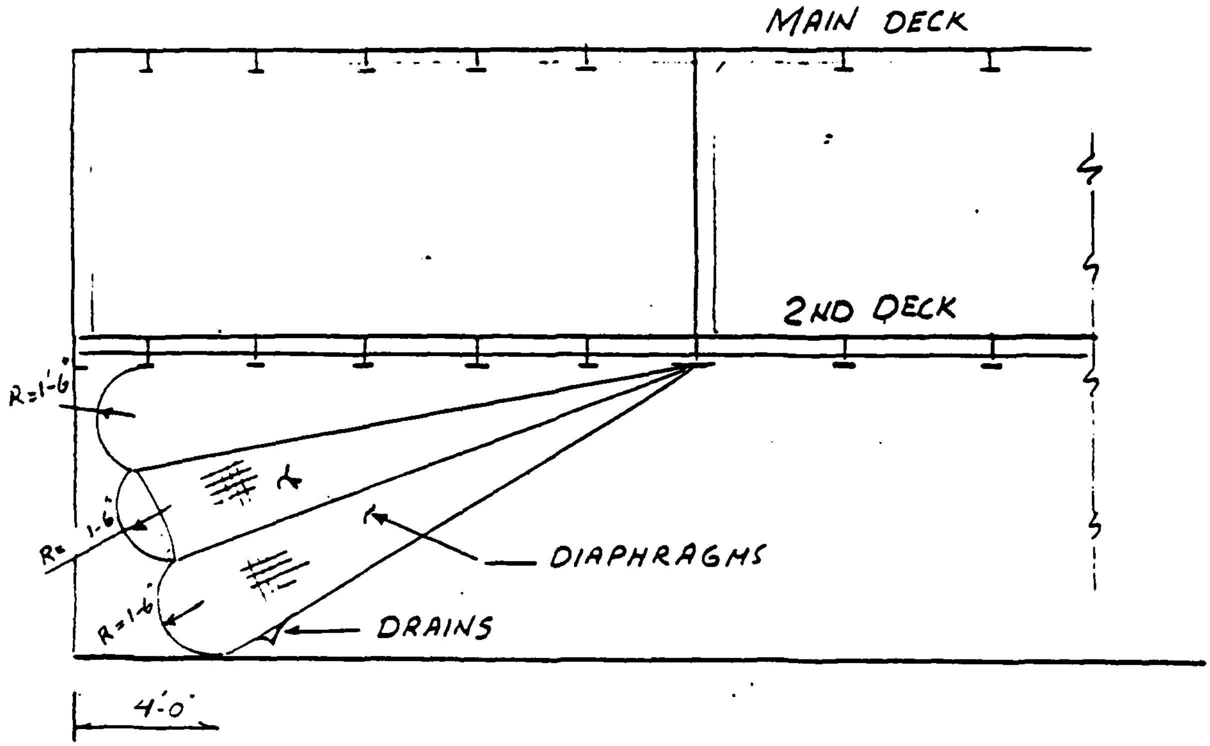


Figure 4.4-9. WPC-SES Stern Seal Schematic

Table 4.4-2. WPC-SES Seal Materials

MATERIAL CHARACTERISTICS	BAG		PARASOL (NOTE (1))
	BOW	STERN	
Fabric Type	Nylon 3x4 (Basket Weave)	Nylon 3x4 (Basket Weave)	Nylon 3x4 (Basket Weave)
Coating Type[(2)]	Neoprene Base Rubber	Neoprene Base Rubber	Neoprene Base Rubber
Material Weight	90 Oz/Yd^2	90 Oz/Yd^2	90 Oz/Yd^2
Tensile Strength — Warp	1200 ply	1200 ply	1200 ply
Tensile Strength — Fill	1200 ply	1200 ply	1200 ply
Tear Strength	200 ply	200 ply	200 ply

Notes:

(1) Parasol stiffening elements (battens) have the following dimensions:

Thickness = 0.1 In.

Width = 1-1/2 In.

Length ≈ 12 In

The battens are made from glass reinforced plastic (Scotchply 1002) The fibers are unidirectional and are parallel to the long side of the batten. The batten material properties are as follows:

Flexural Strength	=	165,000 psi	Room Temperature and Dry
Modulus in Flexure	=	5.3×10^6 psi	Room Temperature and Dry
Tensile Strength	=	160,000 psi	Room Temperature and Dry
Specific Gravity	=	1.8	Room Temperature and Dry

(2) Alternate seal coating may be Chemigum vinyl (Goodyear M-521) fabric type, maybe Goodyear H391.

emergency and/or uninterruptible power. Two solid state 60 Hz/400 Hz frequency converters are employed to provide 400 Hz power as required with one operational and the other on standby under normal operating conditions. A diagram of the electrical power distribution concept is shown in Figure 4.4-10.

4.5 COMMAND COMMUNICATION AND CONTROL -- Three command, communication and control spaces are provided:

1. A Coordination, Control and Communication Center on the Main Deck.
2. A Pilot House located on the 01 level immediately above the Main Deck Coordination Control and Communication Center.
3. A Machinery Control Center located on the Second Deck immediately below the Coordination Control and Communication Center.

The Coordination, Control and Communication Center serves as the primary control station for navigation, tactical command, and both external and internal communications.

The Pilot House serves as the primary control station for ship maneuvering, and collision avoidance. Limited control of propulsion and lift machinery is provided in the Pilot House to the extent required for ship handling.

The Machinery Control Center serves as the primary control station for all ship engineering and auxiliary support functions, including control and monitor capability for propulsion, lift auxiliaries, electrical and damage control.

A certain amount of commonality is necessary between the control system functions assigned to the Pilot House and Control Center. Vital ship functions, such as propulsion/lift engine throttle control and communications capability, are duplicated between the two spaces for reliability and safety. Additionally, certain alarms are presented in summary fashion at the Pilot House, with functional control of the monitored equipment being assigned to the Control Center.

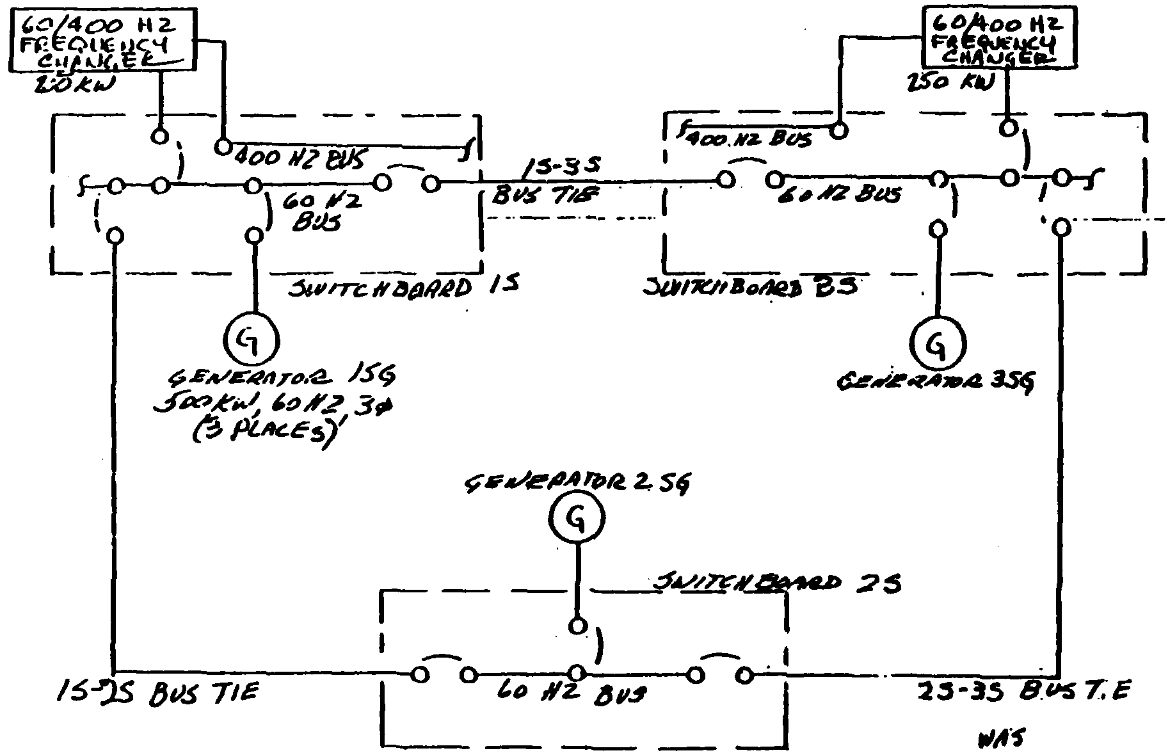


Figure 4.4-10. WPC-SES Power System Distribution Diagram

Redundancy is provided for vital functions with: 1) control consoles in the Pilot House and the Control Center, 2) spatially separated dual remote control paths, and 3) local control.

Navigation equipment is listed in Table 4.4-3.

5. WEIGHT ESTIMATE

The weight estimate is summarized in Table 4.5-1. The lightship weights shown in Table 4.5-1 were derived from parametric analysis of other SES designs and the use of catalogue information for major equipment items. Weights for mission related equipment and variable load items were derived from the design requirements defined in Section 3.

6. PERFORMANCE

The performance characteristics in terms of power, speed, range, ride quality, hydrostatic characteristics and stability are summarized below.

6.1 SPEED, DRAG, AND SEA-STATE RELATIONSHIPS -- The speed, drag, and power relationships for various craft displacements in Sea States 0 through 4 are shown in Figures 4.6-1 through 4.6-4. The powers shown in these figures are 4800 and 4200 HP, based on a fixed pitch propeller.

6.2 RANGE CAPABILITY -- The range capability in Sea States 0 and 2 for 30-knot cushionborne operation and 9-knot (7.5-knot in Sea State 2) hullborne operation is shown in Figures 4.6-5a and 4.6-5b.

6.3 SHIP MOTIONS AND RIDE QUALITY -- The ship motions characteristics at various speed and sea state relative to the U.S. Navy 30 minute and 4 hour ride quality criteria are shown in Figures 4.6-6 through 4.6-9. Note that the characteristics shown are representative of head sea conditions. Some improvement in ride quality may be accomplished by adjustment of the ship's heading to avoid the head sea condition.

6.4 HYDROSTATIC CHARACTERISTICS -- The hydrostatic characteristics as derived from the lines drawing shown in Figure 4.4-2 are presented in Figures 4.6-10 through 4.6-16.

Table 4.4-3. WPC-SES Navigation and Communication Equipment

NAVIGATION EQUIPMENT	COMMUNICATIONS EQUIPMENT
• RADAR (COLLISION AVOIDANCE) (TWO SYSTEMS) • LORAN-C • SATNAV • RDF • GYRO • FATHOMETER • SPEED LOG • WIND SPEED AND DIRECTION	• VHF (TWO SYSTEMS) • SSB-HF (TWO SYSTEMS) • INTERIOR COMMUNICATION • INTERIOR TELEPHONE

Table 4.5-1. WPC-SES Weight Estimates.

SWBS	ITEM	LONG TONS
100	Hull Structure and Seals	72.0
200	Propulsion and Lift Systems	35.0
300	Electric Power Generation and Distribution System	6.0
400	Command and Surveillance System	0.6
500	Auxiliary Subsystems	23.0
600	Outfit and Furnishings	19.0
700	Combat System	2.8
	Estimated Lightship (without margin)	158.4
	Design and Construction Margin (10%):	15.8
	Design Lightship	174.2
F10	F10 - Personnel	4.7
F23	F23 - Ordnance Delivery Systems	4.4
F30	F30 - Stores	3.0
F42	F42 - Helo Fuel	9.4
F42	F42 - Ships Fuel	41.0
F50	F50 - Liquids and Gases	3.0
/	Mission Related Equipment (Payload)	10.3
	Full Load Displacement (FLD)	250.0

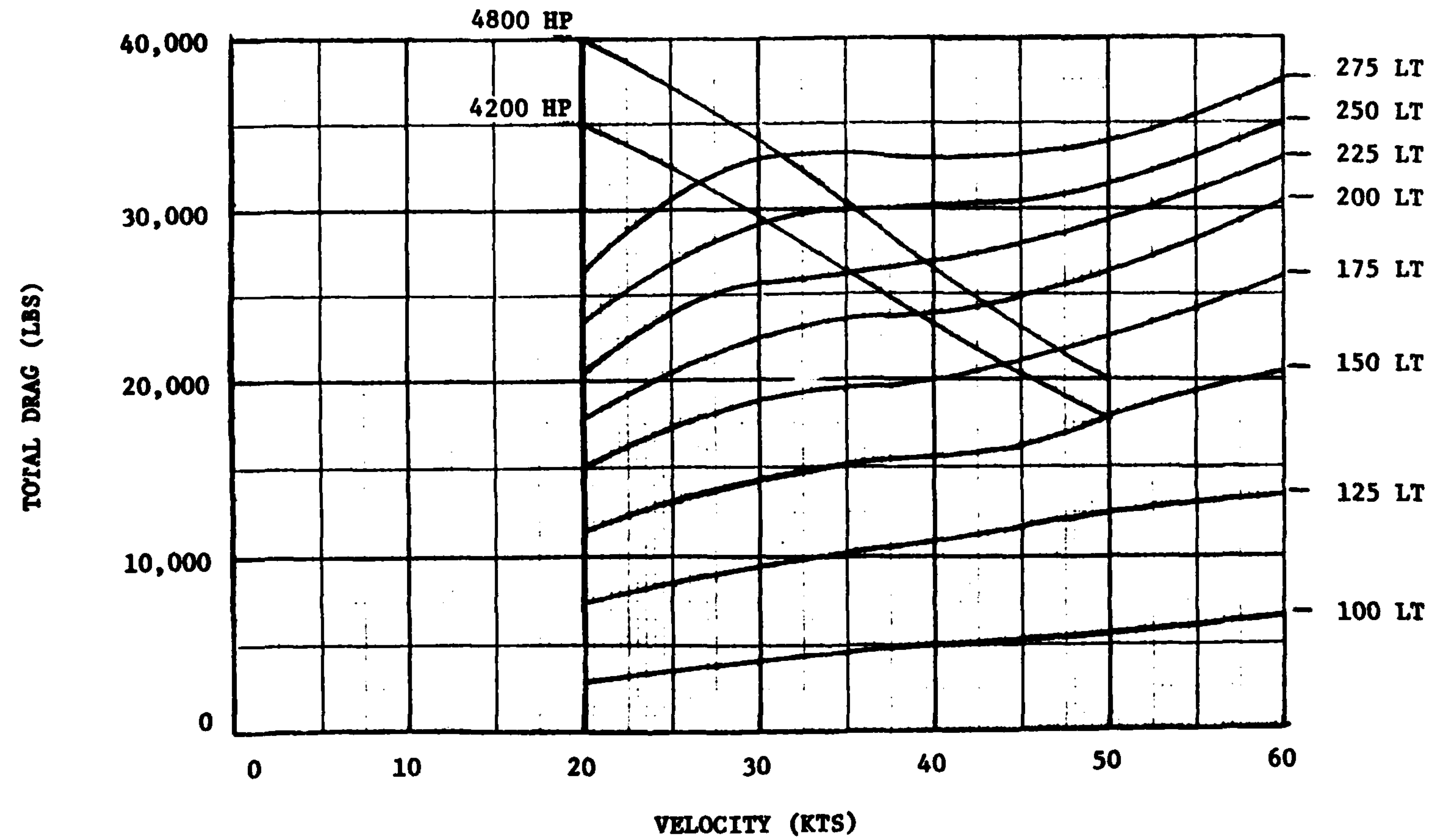


Figure 4.6-1. WPC-SES Speed, Drag and Power - Sea State 0

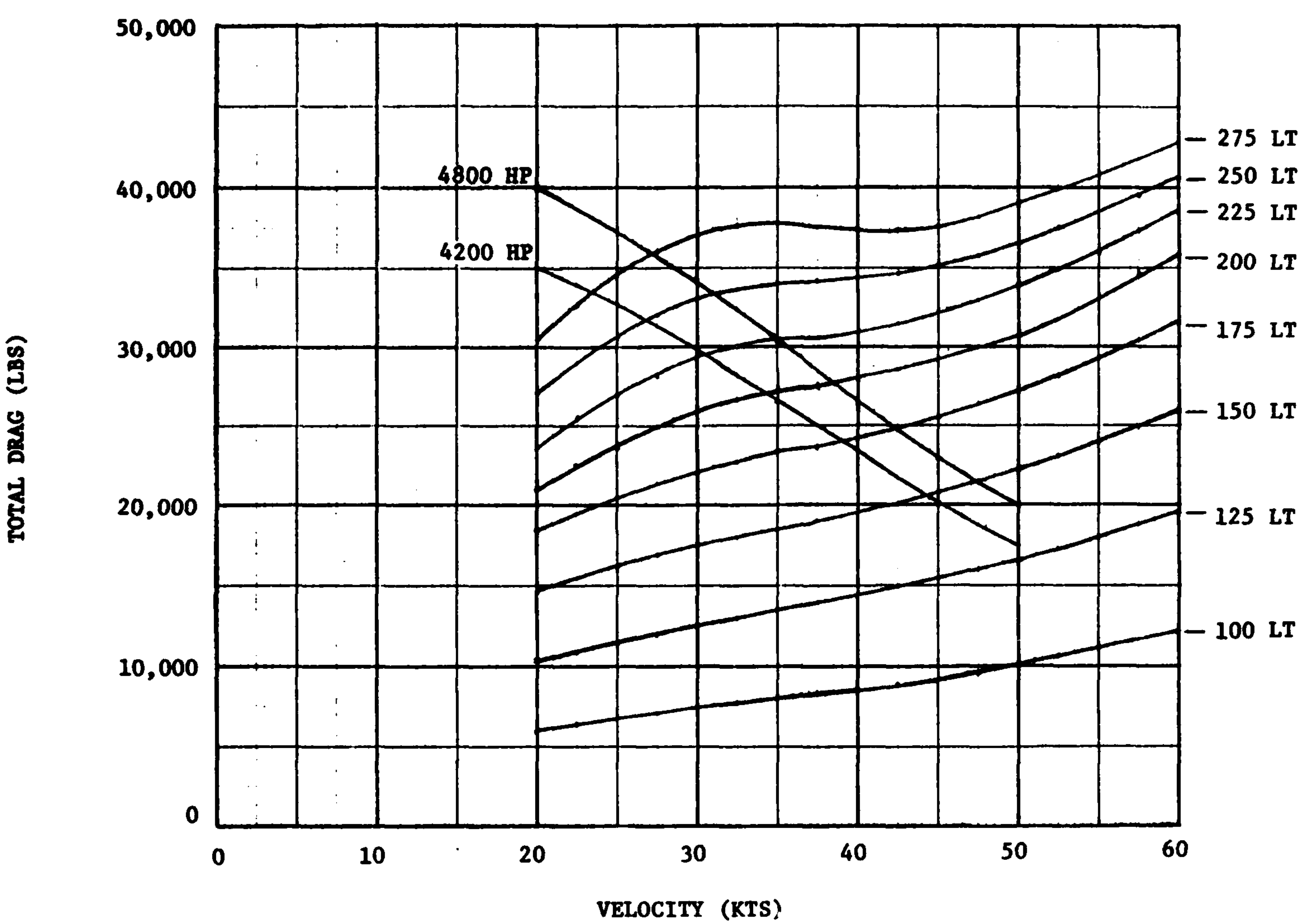


Figure 4.6-2. WPC-SES Speed, Drag and Power - Sea State 2

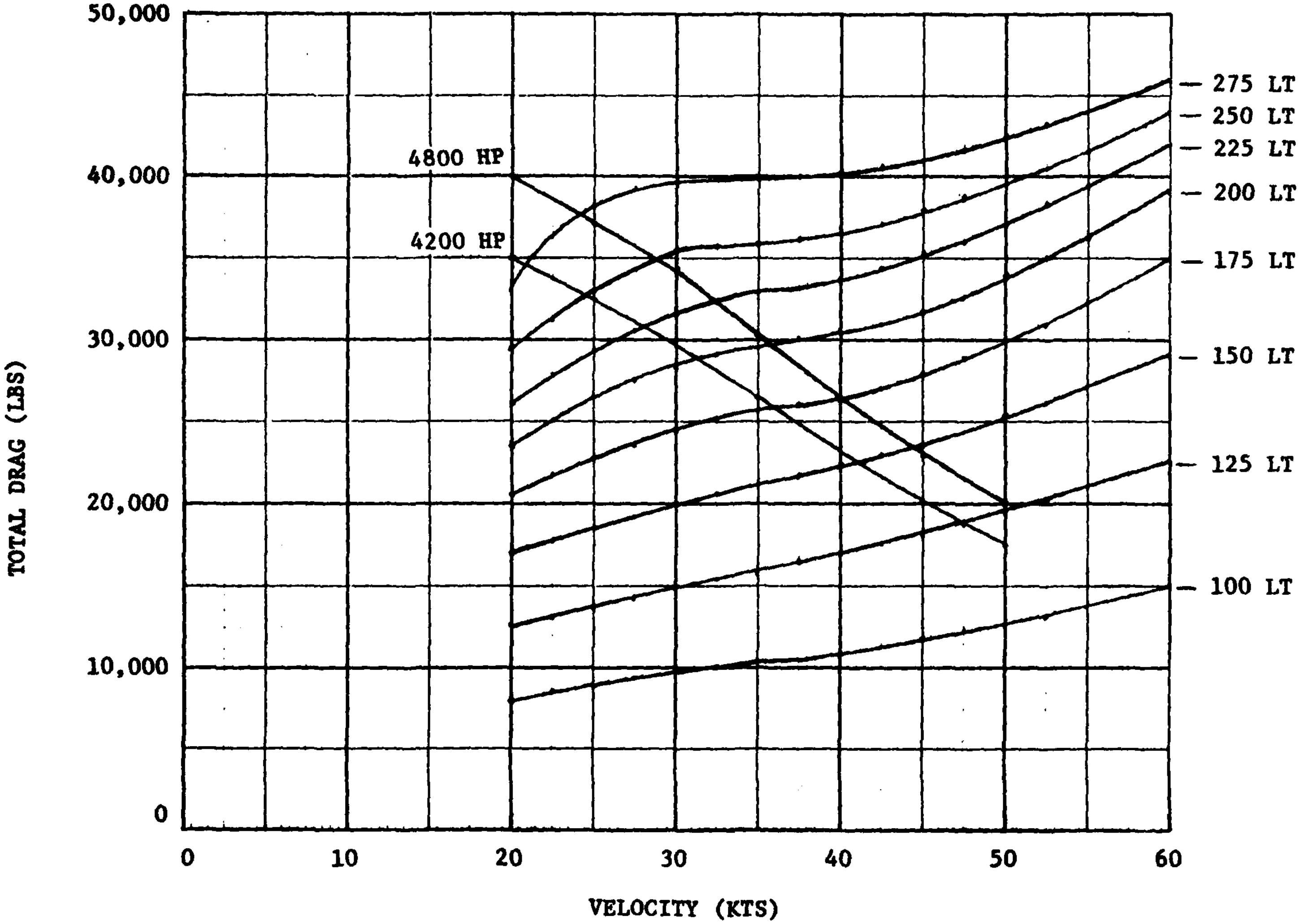


Figure 4.6-3. WPC-SES Speed, Drag and Power - Sea State 3

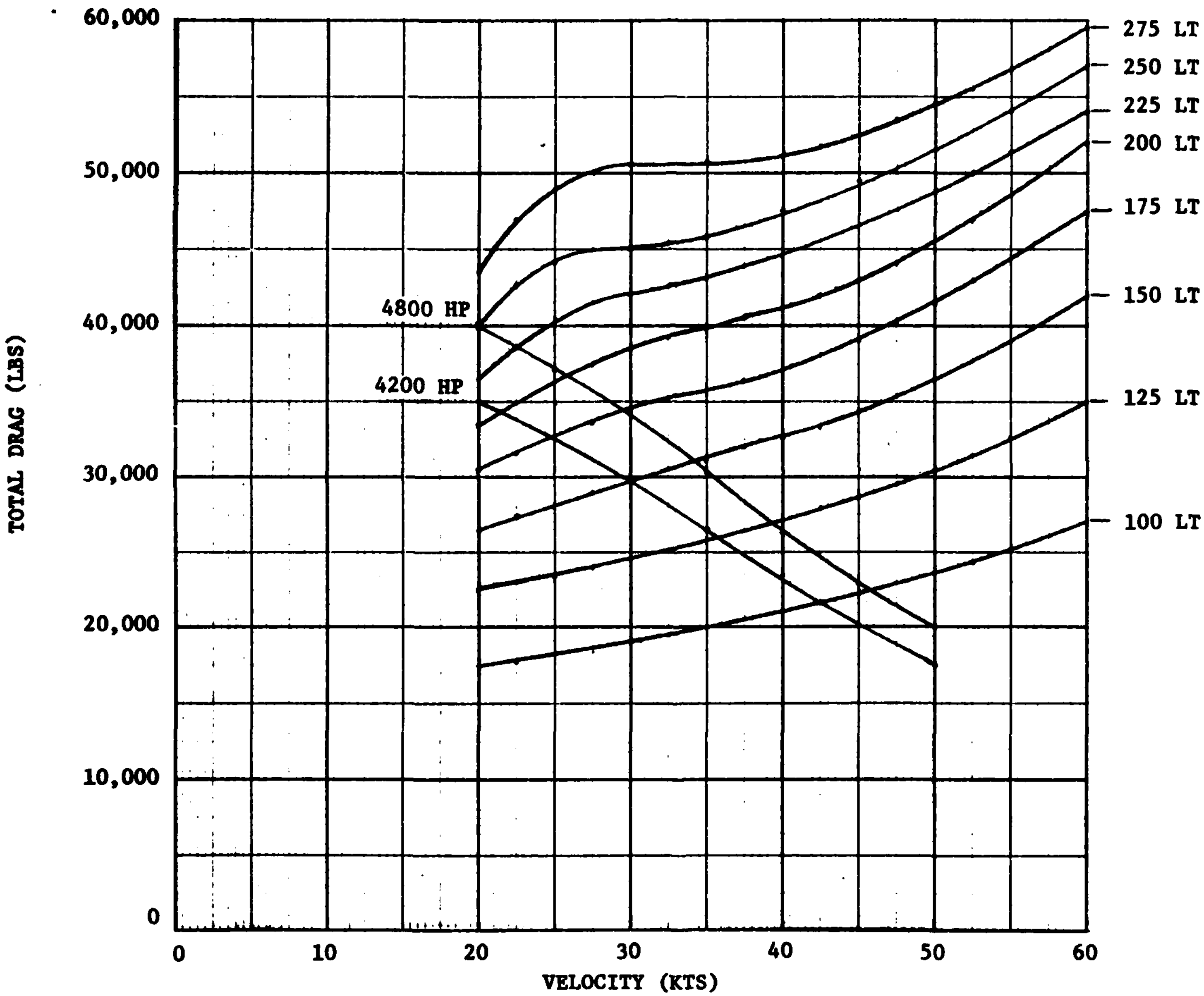


Figure 4.6-4. WPC-SES Speed, Drag and Power - Sea State 4

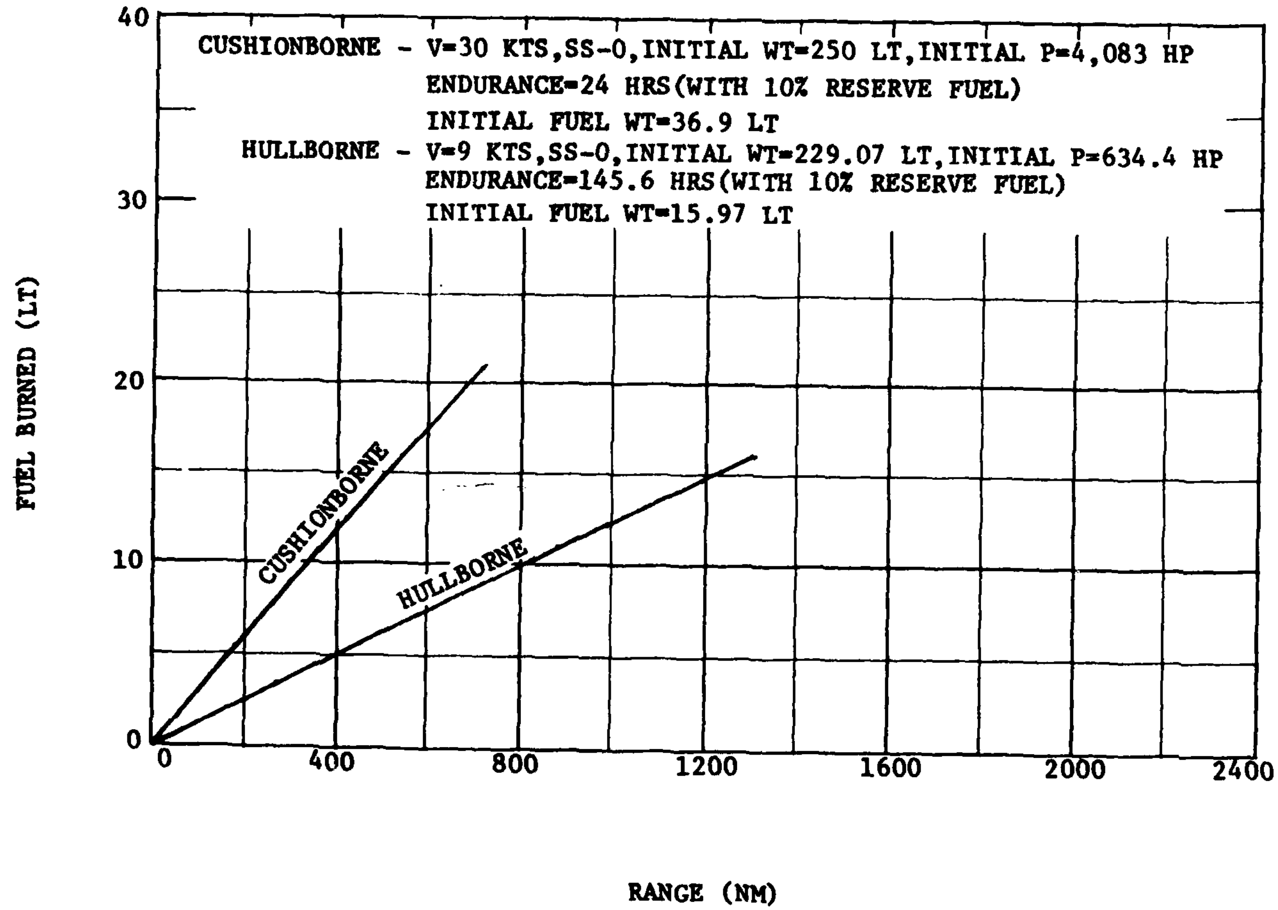


Figure 4.6-5a WPC-SES Range Capability (SS-0)

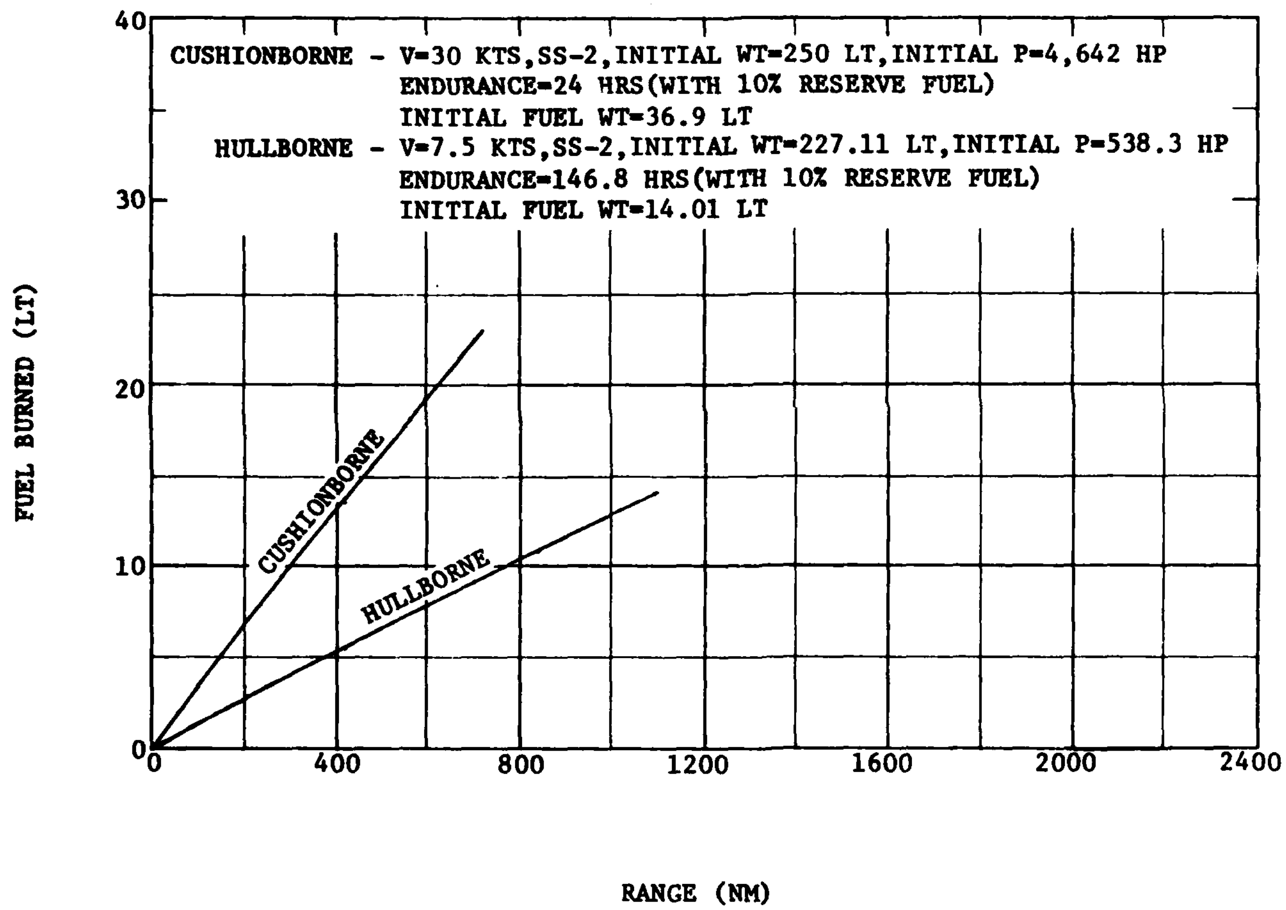


Figure 4.6-5b WPC-SES Range Capability (SS-2)

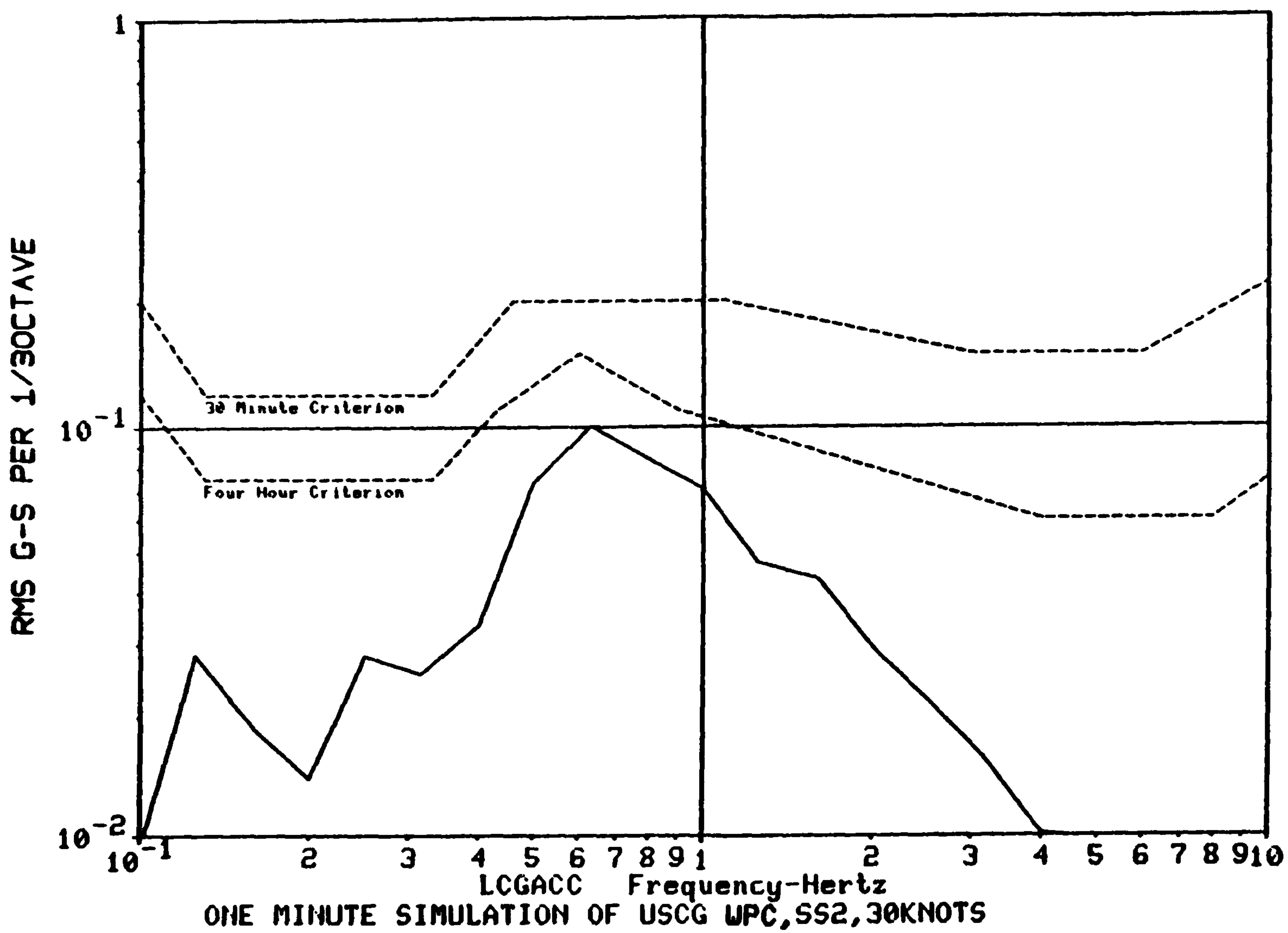


Figure 4.6-6. WPC-SES Ride Quality - 30 Knots - Sea State 2 Cushionborne with Ride Control

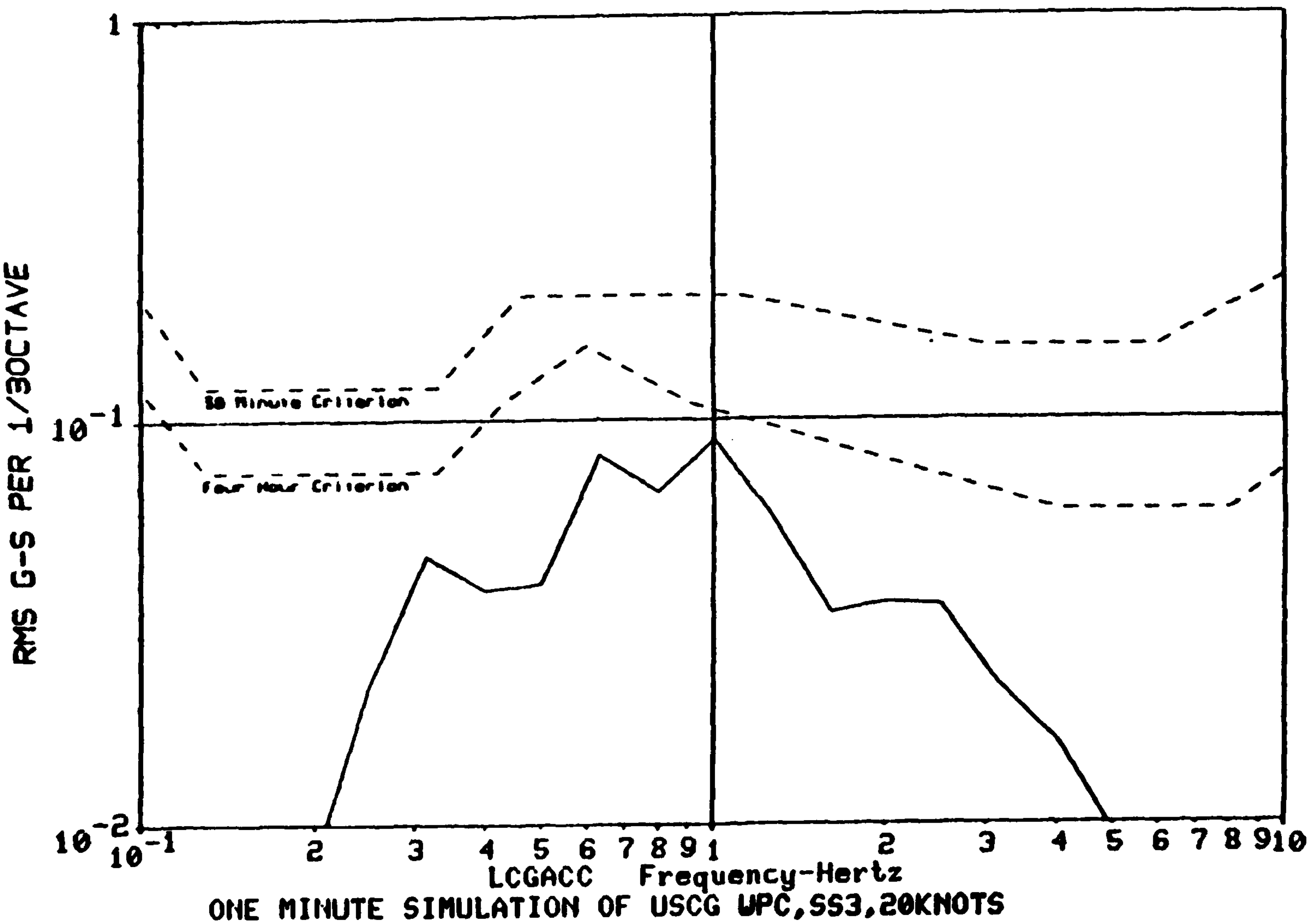


Figure 4.6-7. WPC-SES Ride Quality - 20 Knots - Sea State 3 - Cushionborne with Ride Control

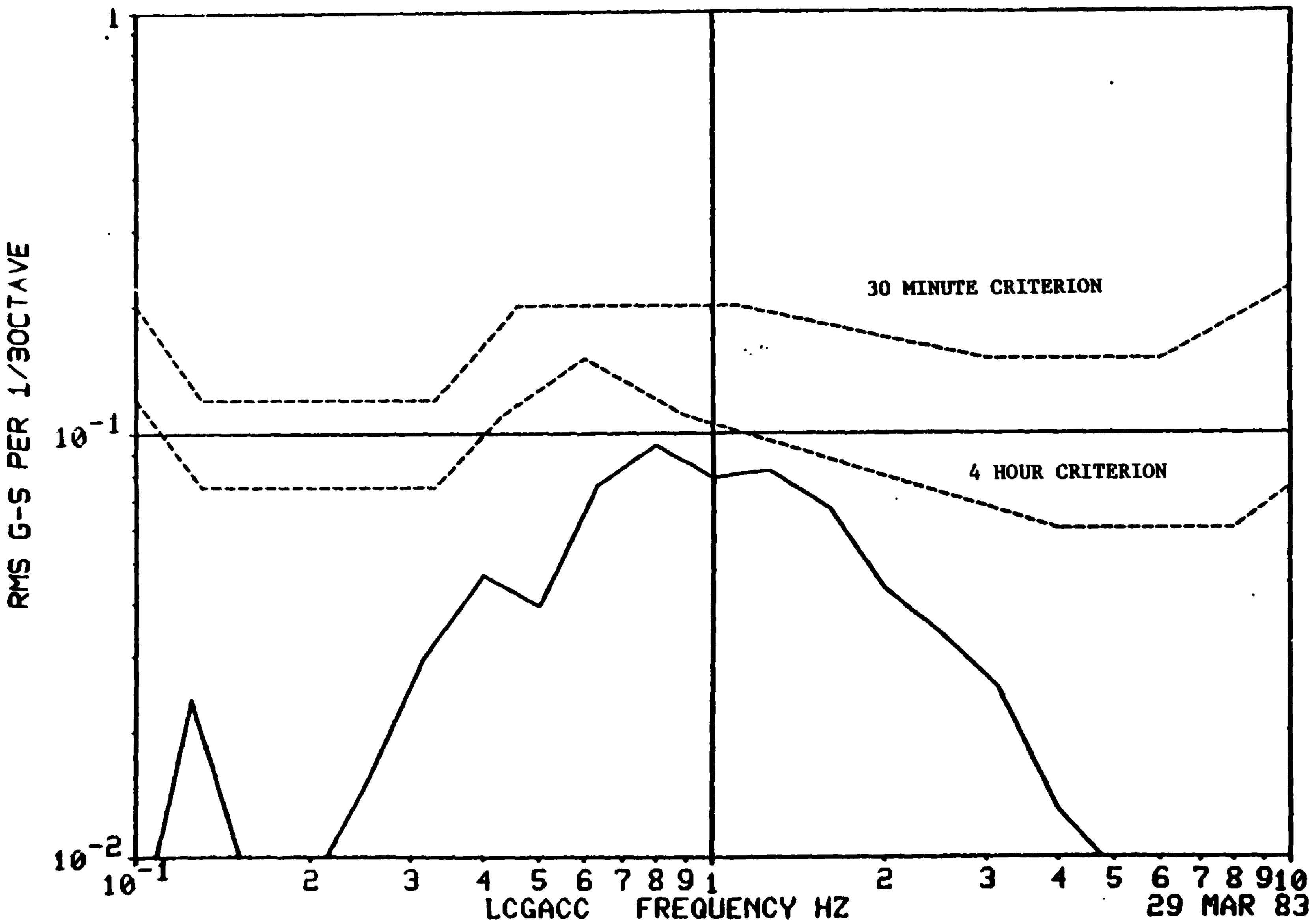


Figure 4.6-8. WPC-SES Ride Quality - 30 Knots - Sea State 3 - Cushionborne with Ride Control

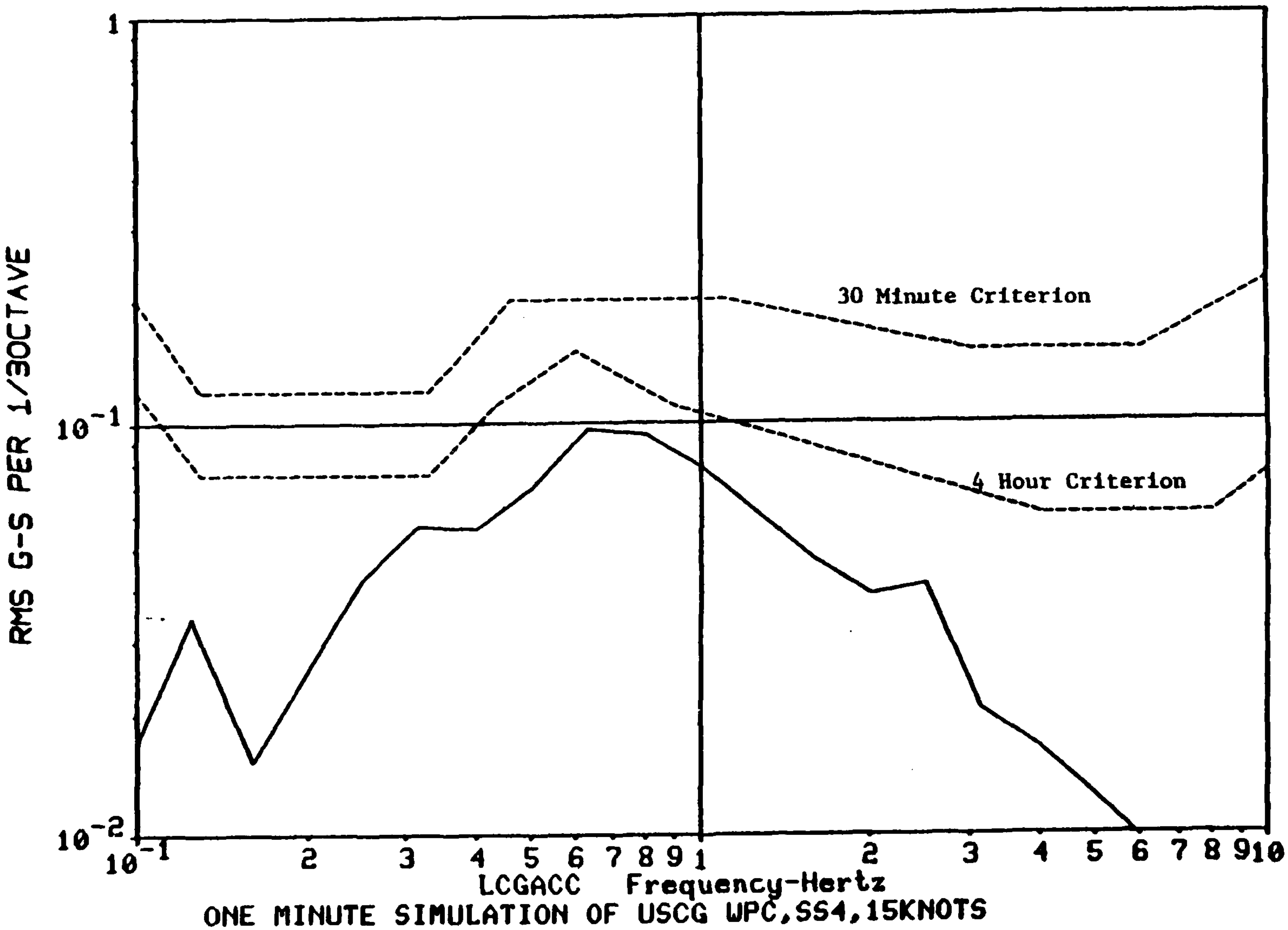


Figure 4.6-9. WPC-SES Ride Quality - 15 Knots - Sea State 4 - Cushion' .rne with Ride Control

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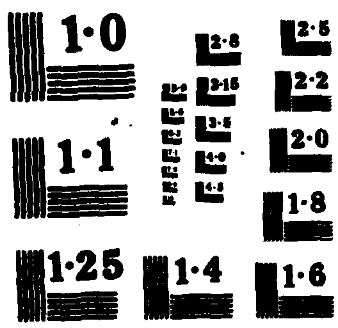
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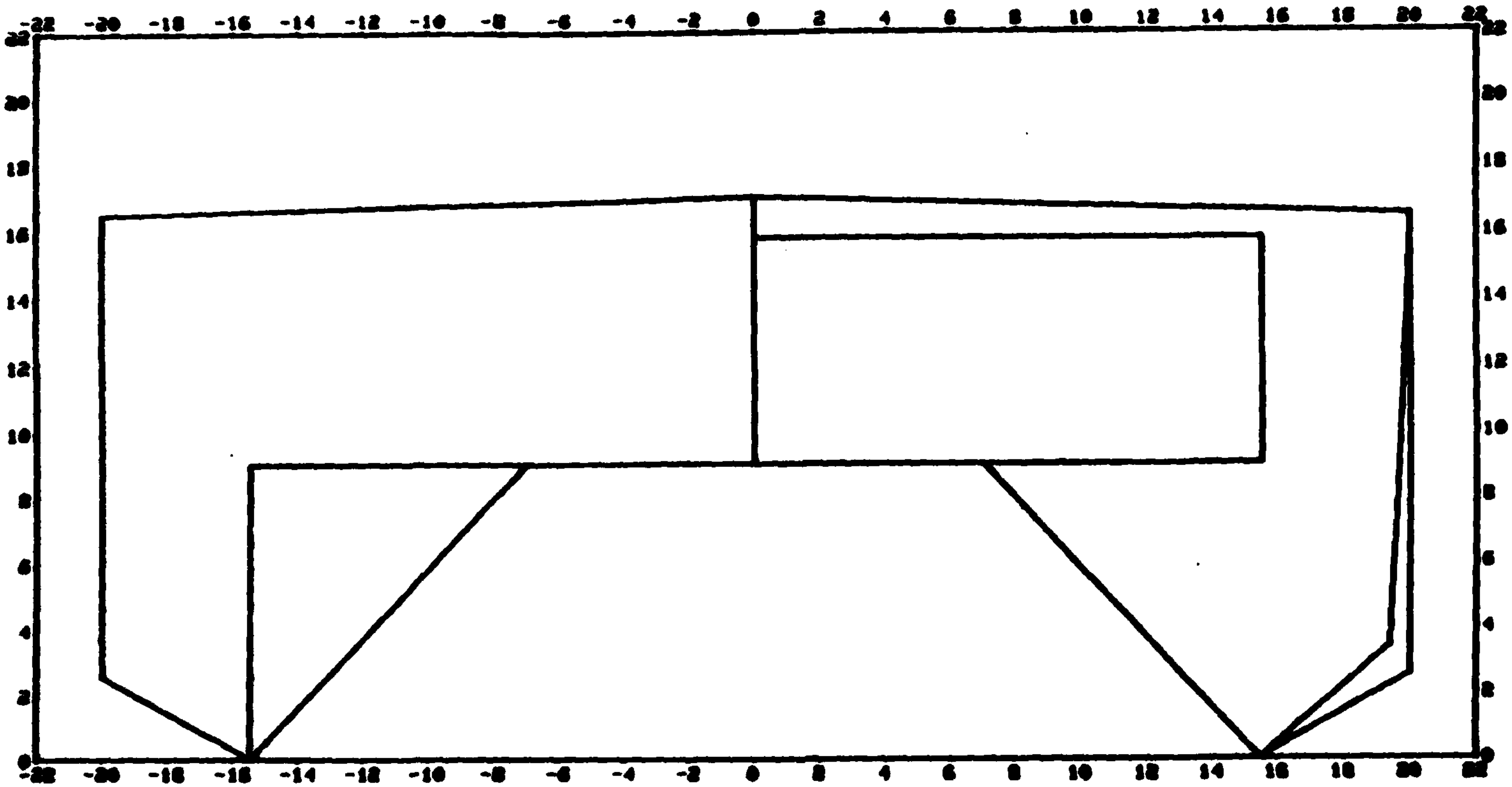


Figure 4.6-10. WPC-SES Hydrostatic Analysis Hull Section

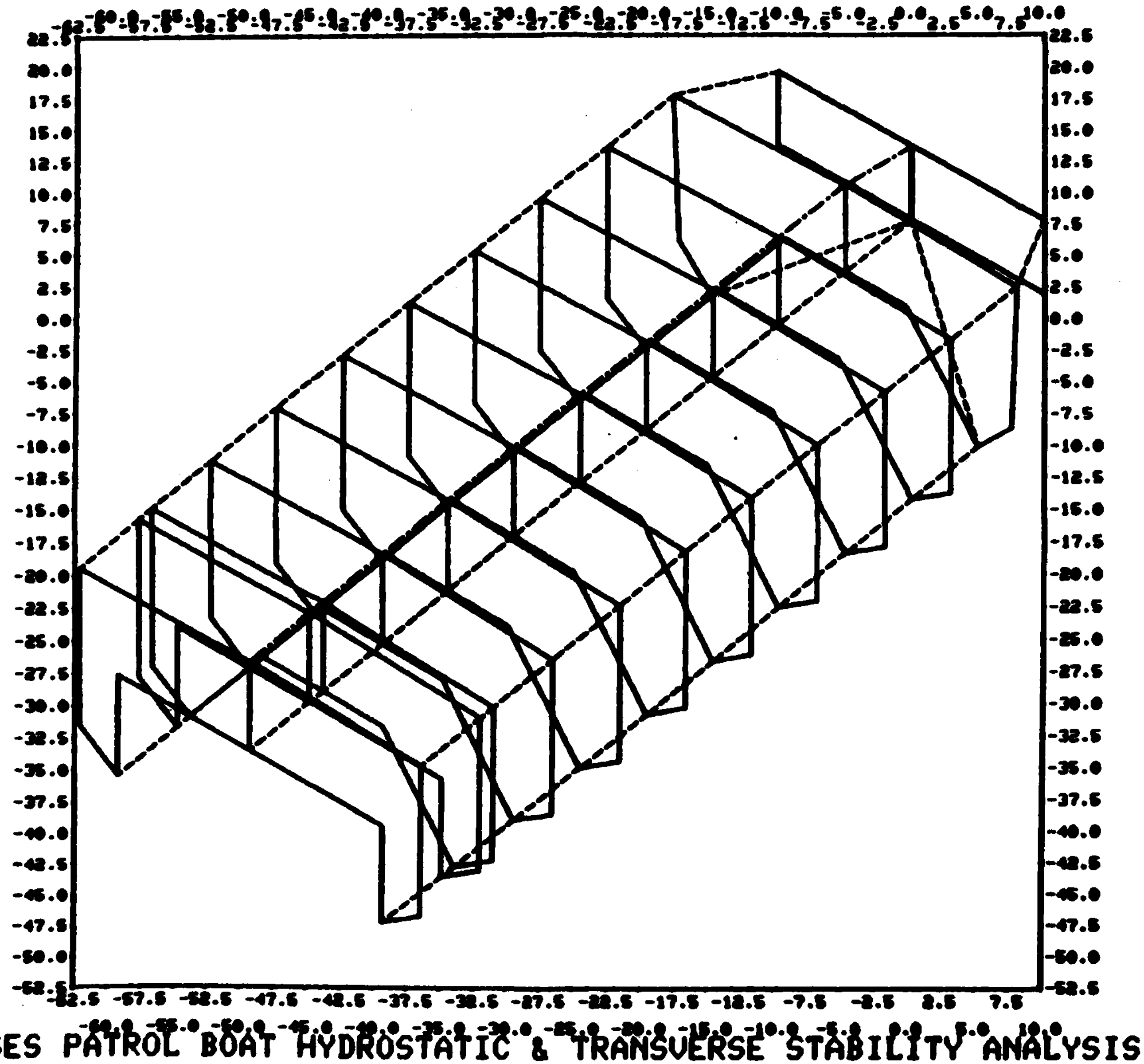
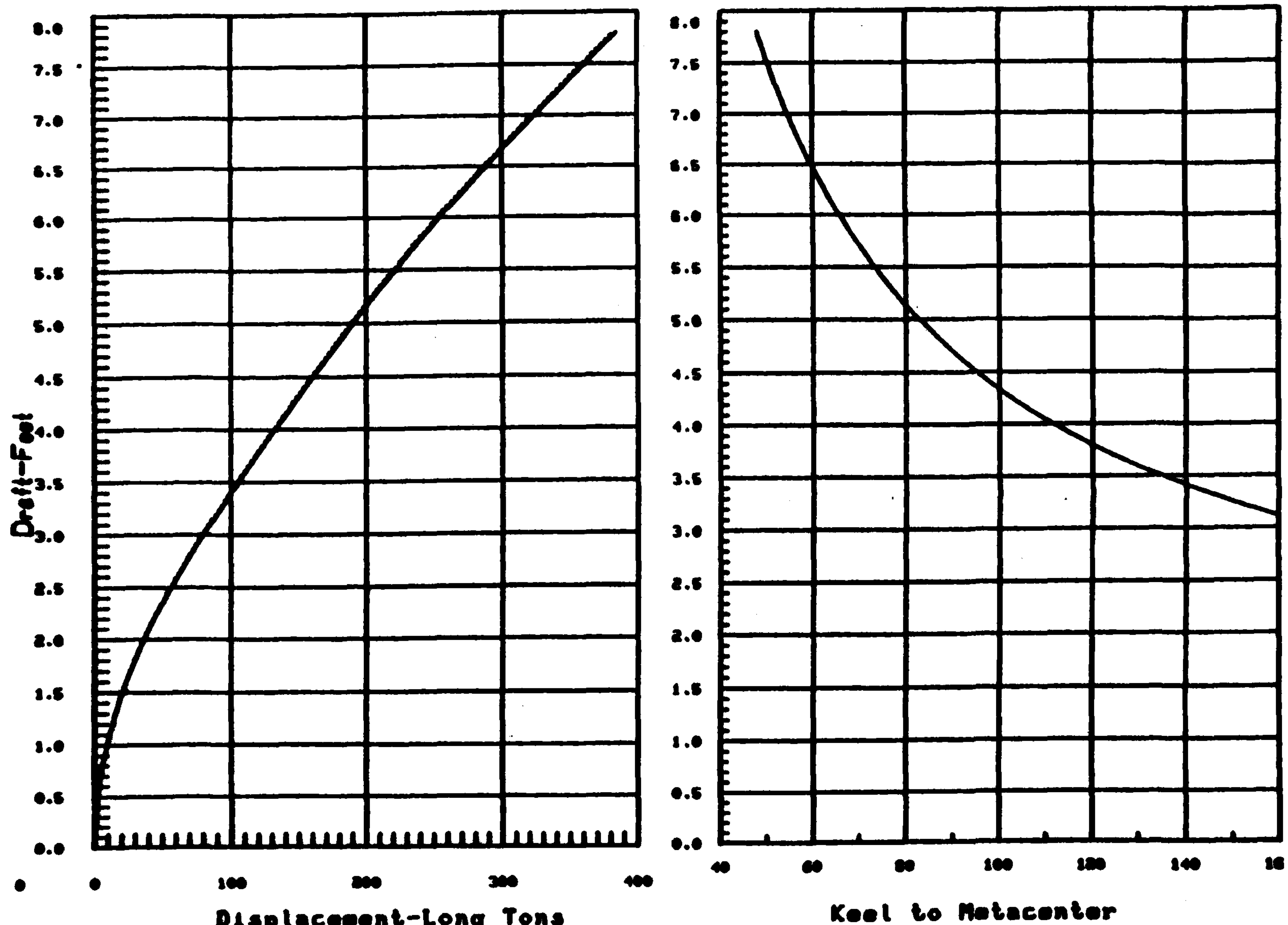


Figure 4.6-11. WPC-SES Hydrostatic Analysis - Hull Geometry



USCG SES PATROL BOAT HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 4.6-12. WPC-SES Displacement, Draft, and Transverse Metacenter

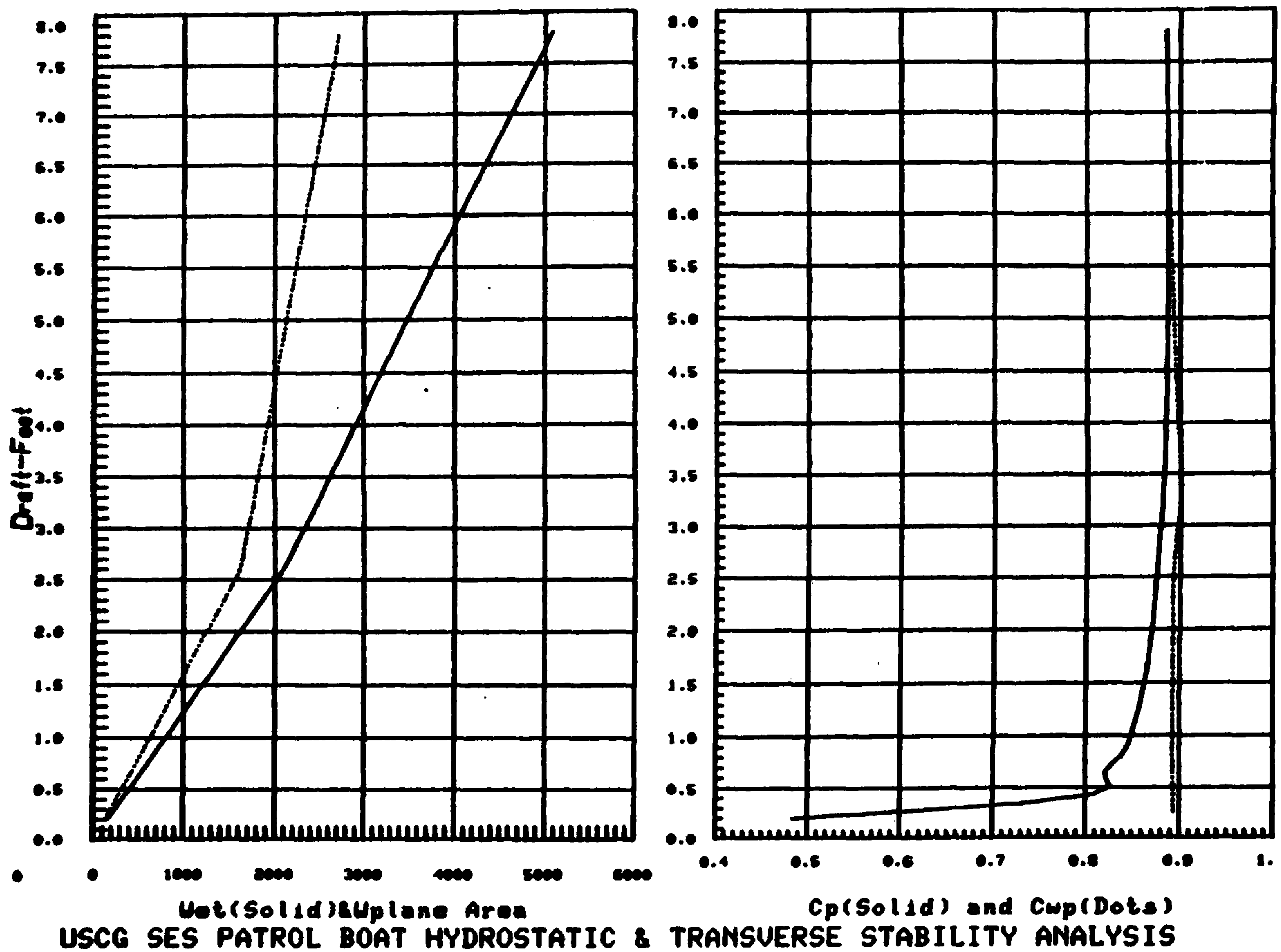


Figure 4.6-13. WPC-SES Waterplane Area, Prismatic Coefficient and Waterplane Area Coefficient

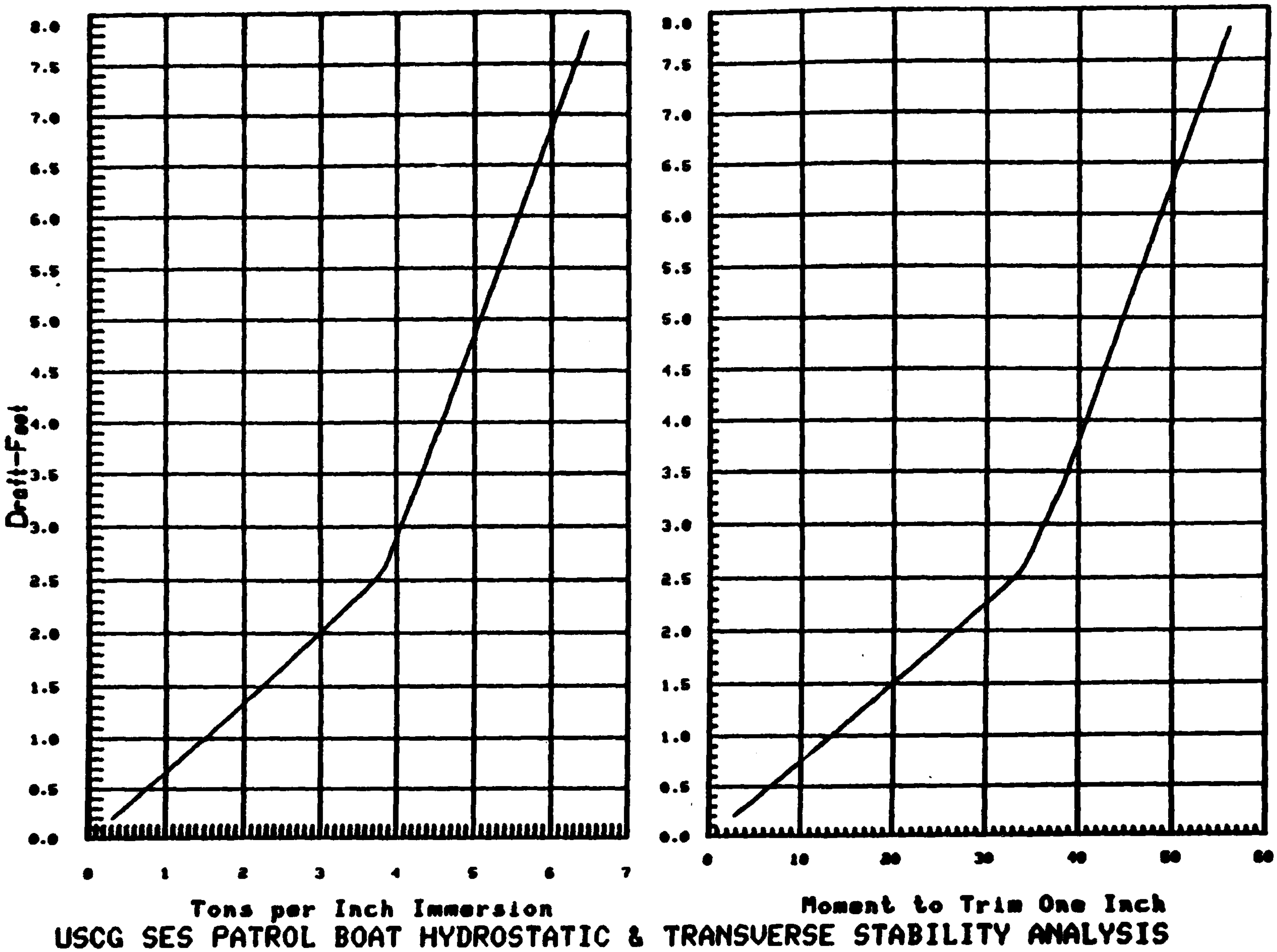


Figure 4.6-14. WPC-SES Tons Per Inch Immersion and Moment to Change Trim One Inch

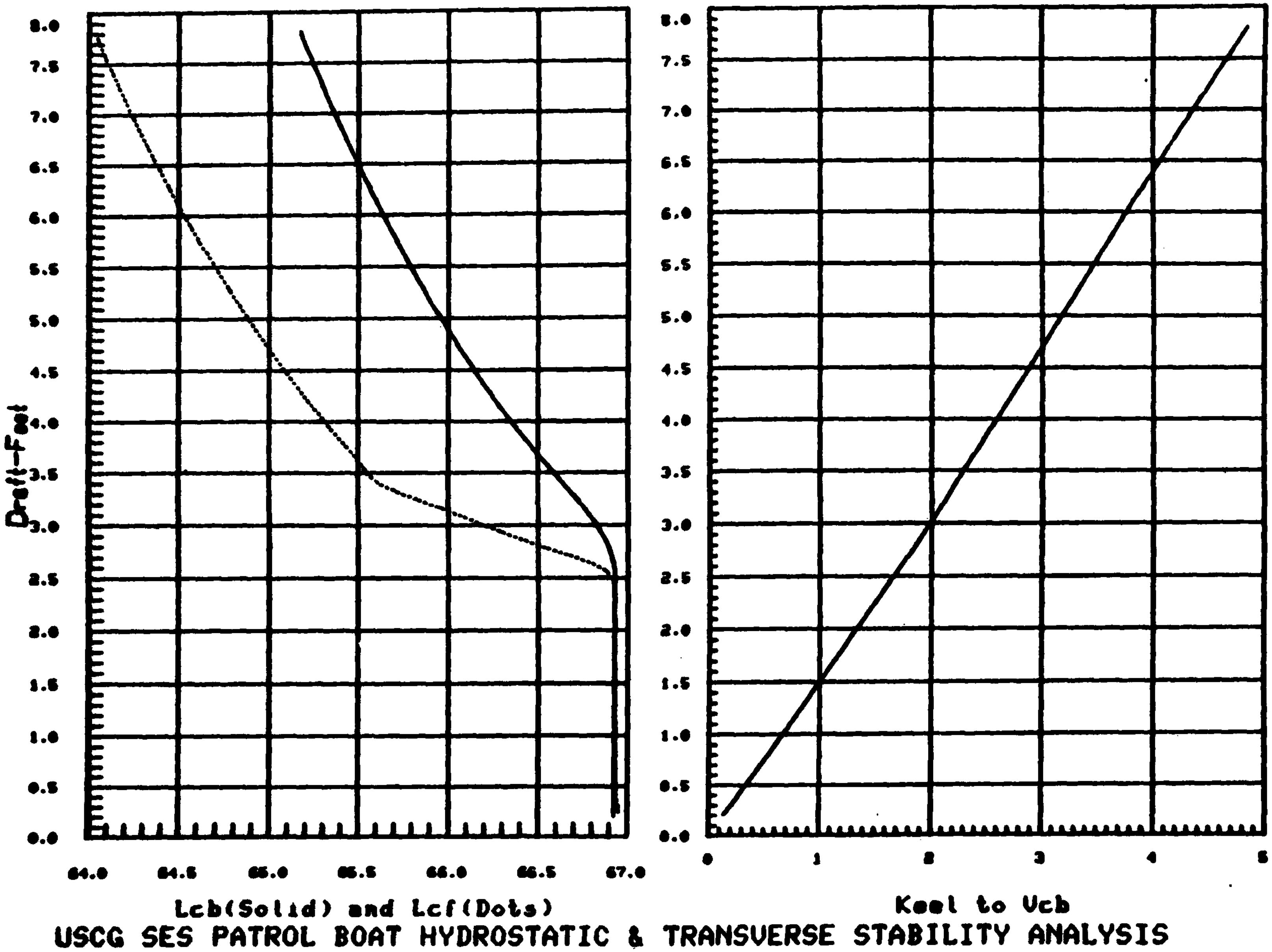


Figure 4.6-15. WPC-SES LCB, LCF and VCB

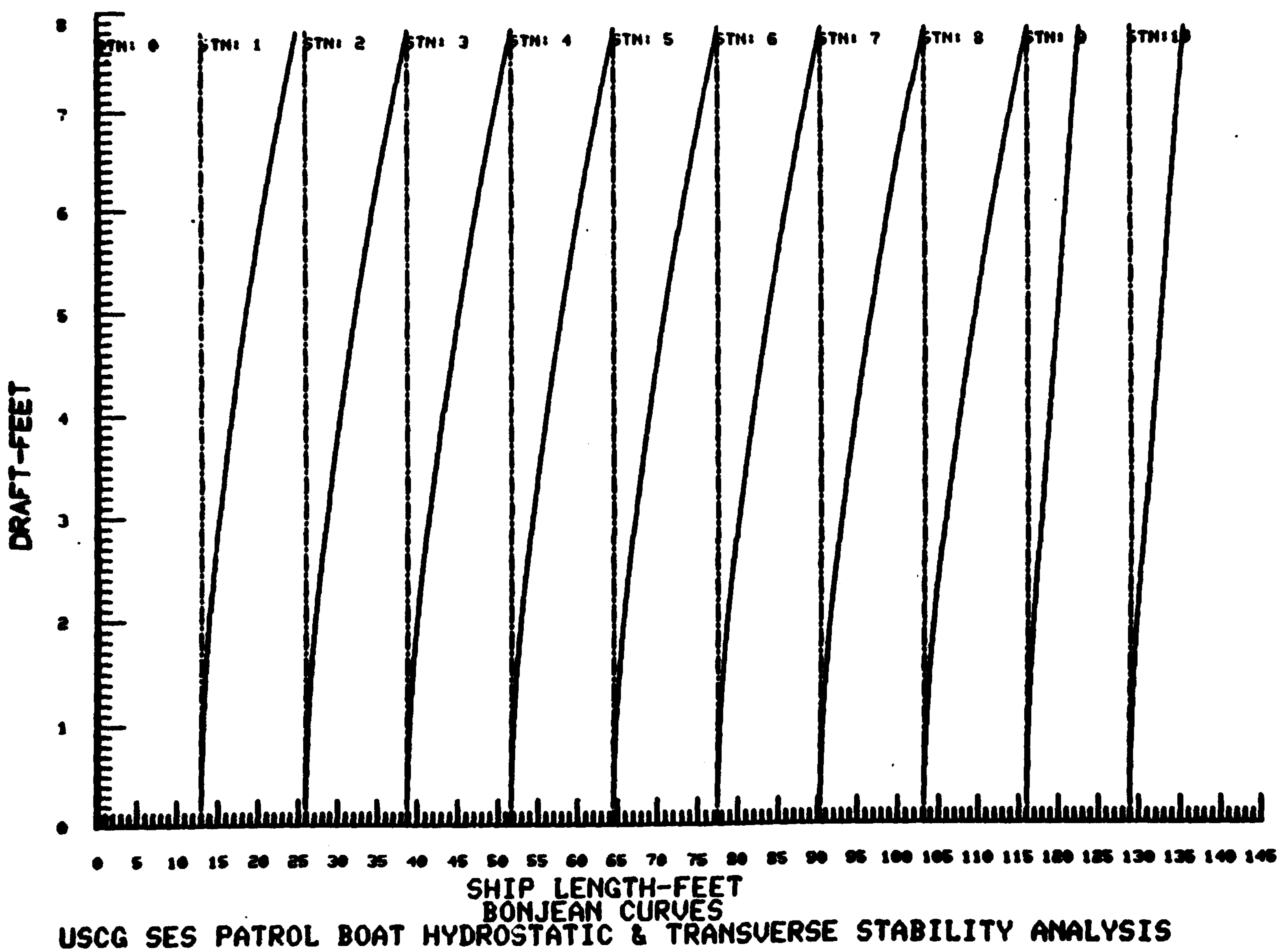


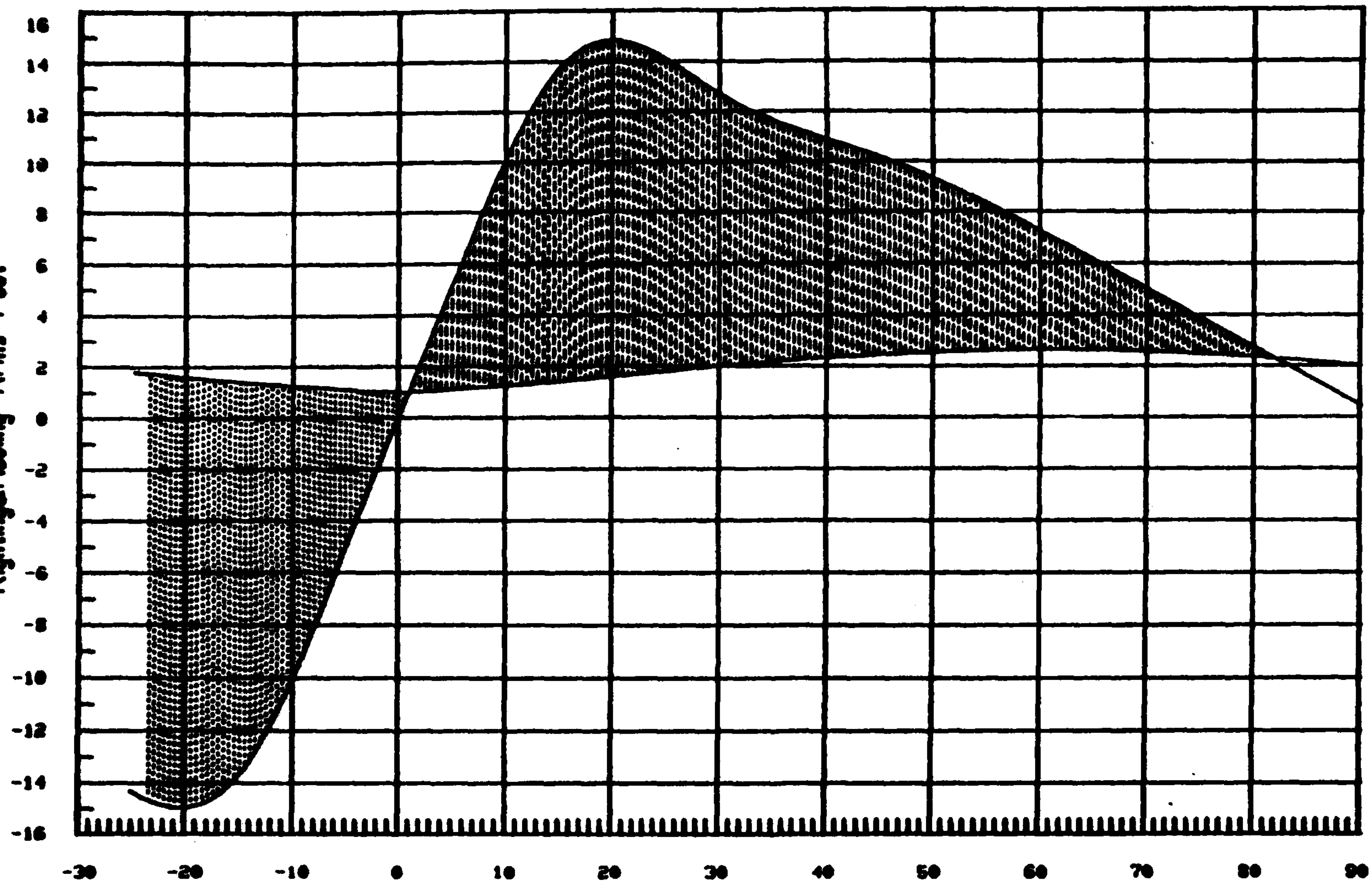
Figure 4.6-16. WPC-SES Bonjean Curves

6.5 INTACT STABILITY

The intact stability characteristics in the full load condition and burned out condition are shown in Figures 4.6-17 and 4.6-18 respectively. As shown in the Figures the craft satisfies the intact stability criteria of DDS 079-1 "Stability and Buoyancy of U.S. Naval Surface Ships" in both conditions.

6.6 DAMAGE STABILITY

The assessment of stability under various conditions of the compartment damage is shown in Figures 4.6-17 through 4.6-26. As shown the craft satisfies the requirements of DDS 079-1 under all damage conditions investigated. The assessment was based upon an intact full load displacement condition. A permeability of ninety-five percent was assumed for all areas subject to flooding.



U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.40

Hydrostatic Properties for Ship in Intact Condition — Rolling Angle=25 Degrees — A1/A2= 2.08

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
250.0	129.0	40.0	5.9	16.5	0.0	8.5	65.7	48.4	5.5	0.80	0.80	58.2	80.

Transverse Stability-Beam Wind Combined with Rolling

USCG SES PATROL BOAT HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 4.6-17. WPC-SES Intact Stability Wind Heel Full Load Condition

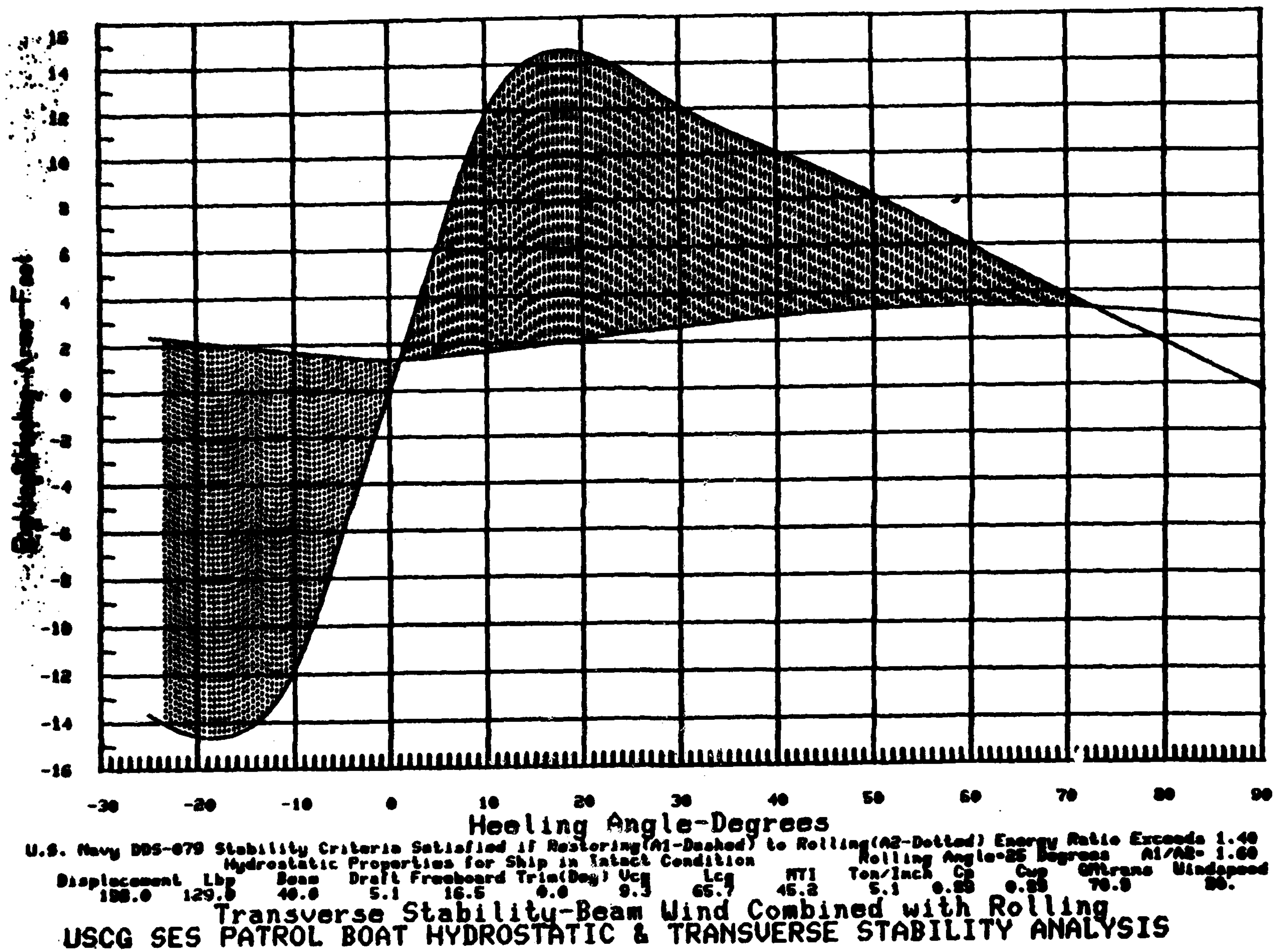
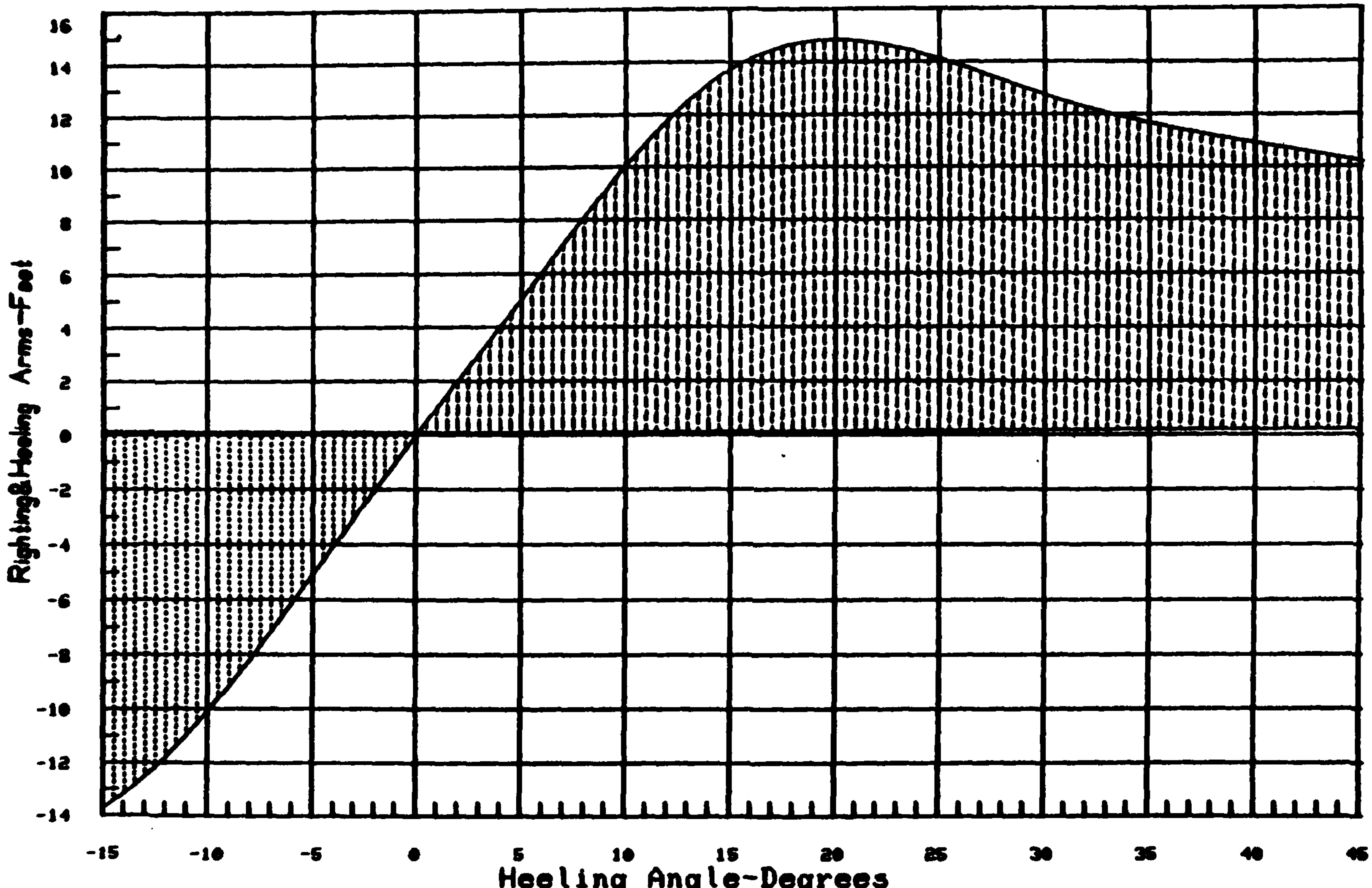


Figure 4.6-18. WPC-SES Intact Stability Wind Heel Burned Out Condition

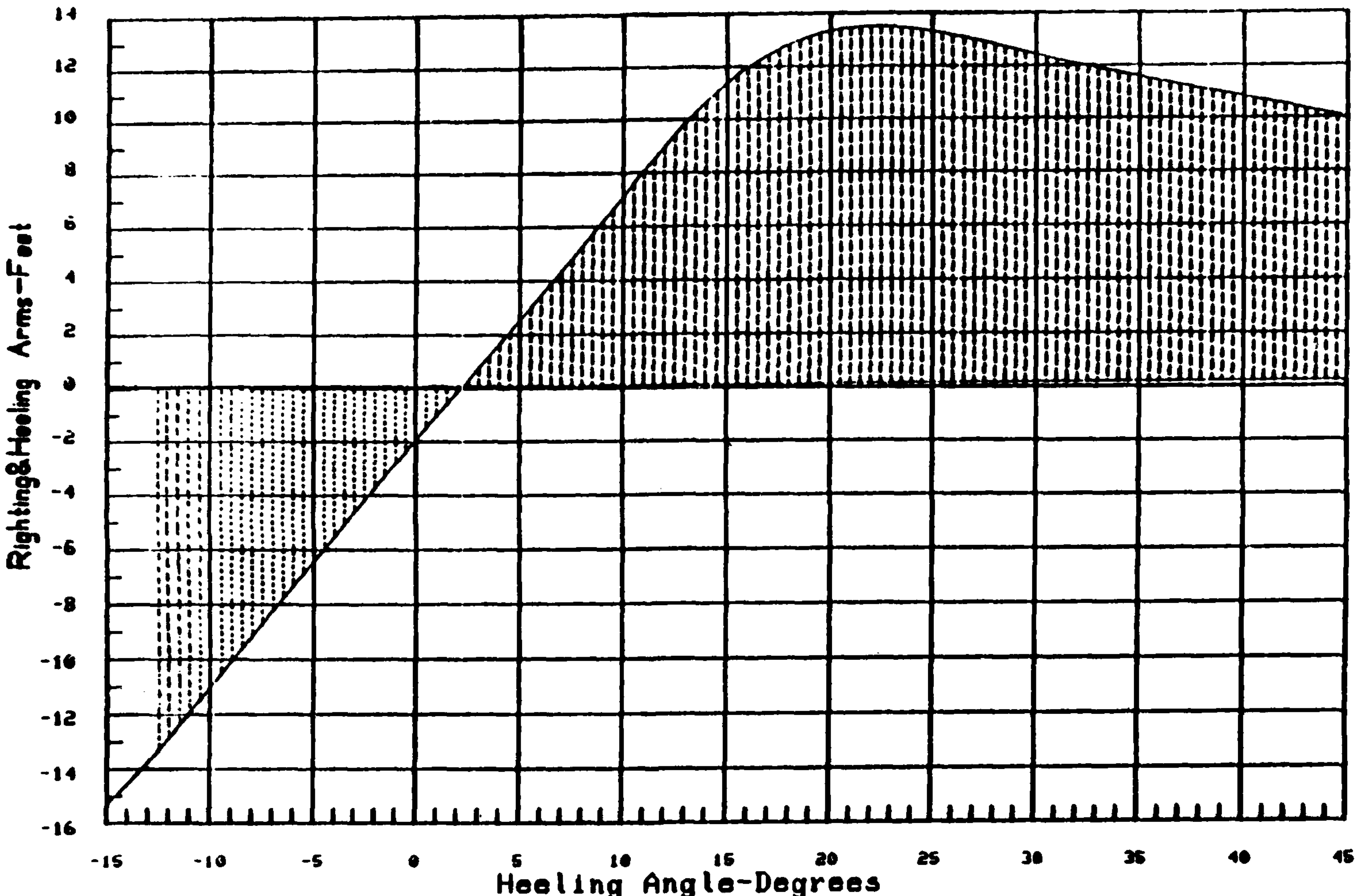


U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 1 and 22 Permeability(Port)=0.95 Permeability(Starboard)=0.95 Rolling Angle=15 Degrees A1/A2= 4.68

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
250.0	129.0	40.0	5.9	16.4	0.0	8.5	65.7	0.0	0.0	0.00	0.00	-8.5	85.

Transverse Stability-Beam Wind Combined with Rolling
USCG SES PATROL BOAT HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 4.6-19. WPC-SES Damage Stability Compartments 1 and 2, Shell-to-Shell Damage



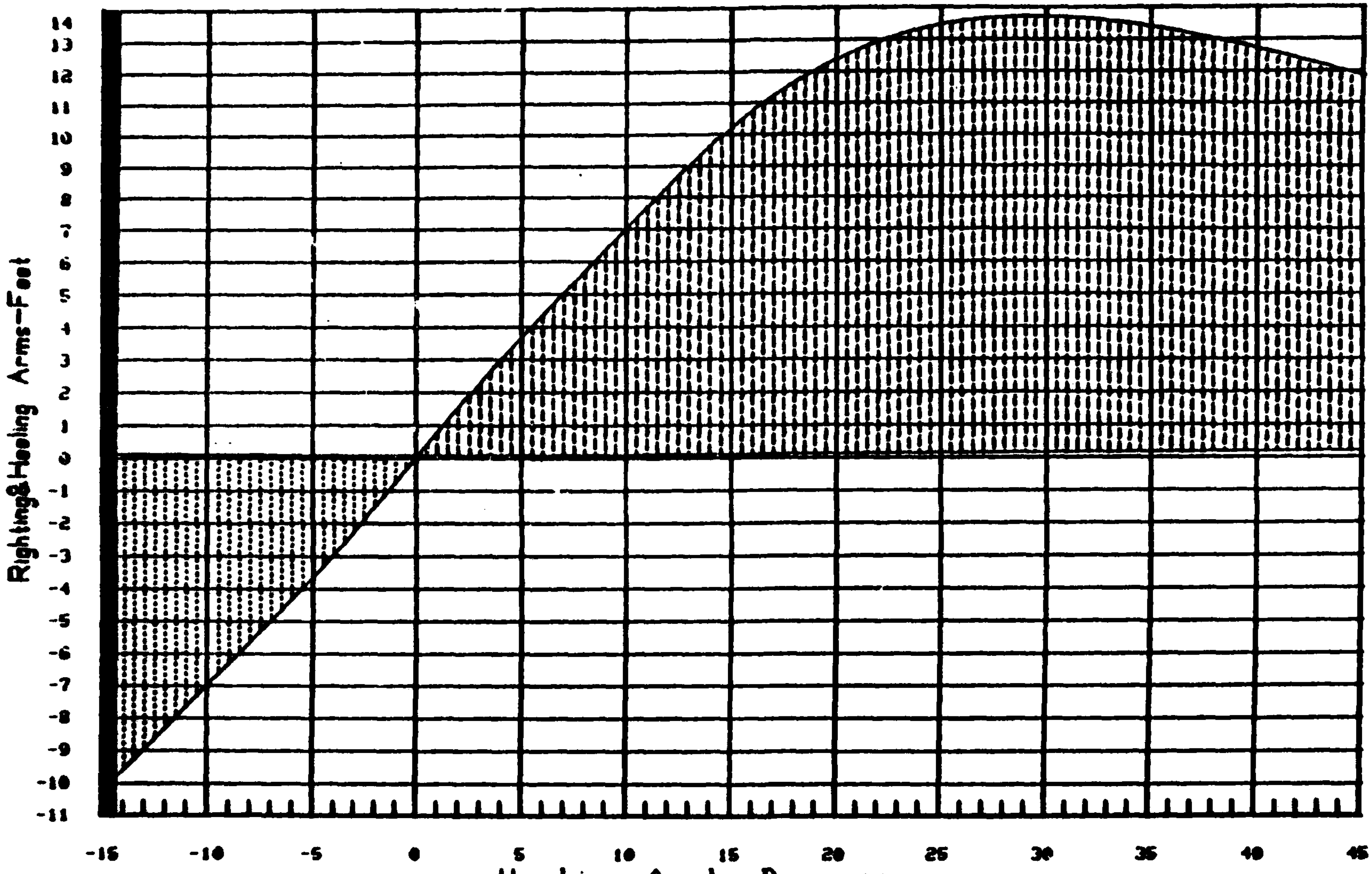
U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 14 and 52 Permeability(Port)-0.00 Permeability(Starboard)-0.95 Rolling Angle-15 Degrees A1/A2- 4.35

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
250.0	129.0	40.0	6.9	16.5	-0.5	9.3	65.7	48.4	5.6	0.89	0.89	57.3	25.

Transverse Stability-Beam Wind Combined with Rolling

USCG SES PATROL BOAT HYDROSTATIC & TRANSVERSE STABILITY ANALYSIS

Figure 4.6-20. WPC-SES Damage Stability Compartments 2 and 3, Shell-to-Shell Damage



U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 22 and 81 with Permeability-0.95 Port and 0.95 Starboard Rolling Angle-15 Degrees A1/A2- 6.03

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MTI	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
250.0	129.0	40.0	9.9	14.4	-0.3	8.5	68.8	42.1	4.7	0.90	0.90	54.8	85.

Transverse Stability-Beam Wind Combined with Rolling

Figure 4.6-21. WPC-SES Damage Stability Compartments 3 and 4, Shell-to-Shell Damage

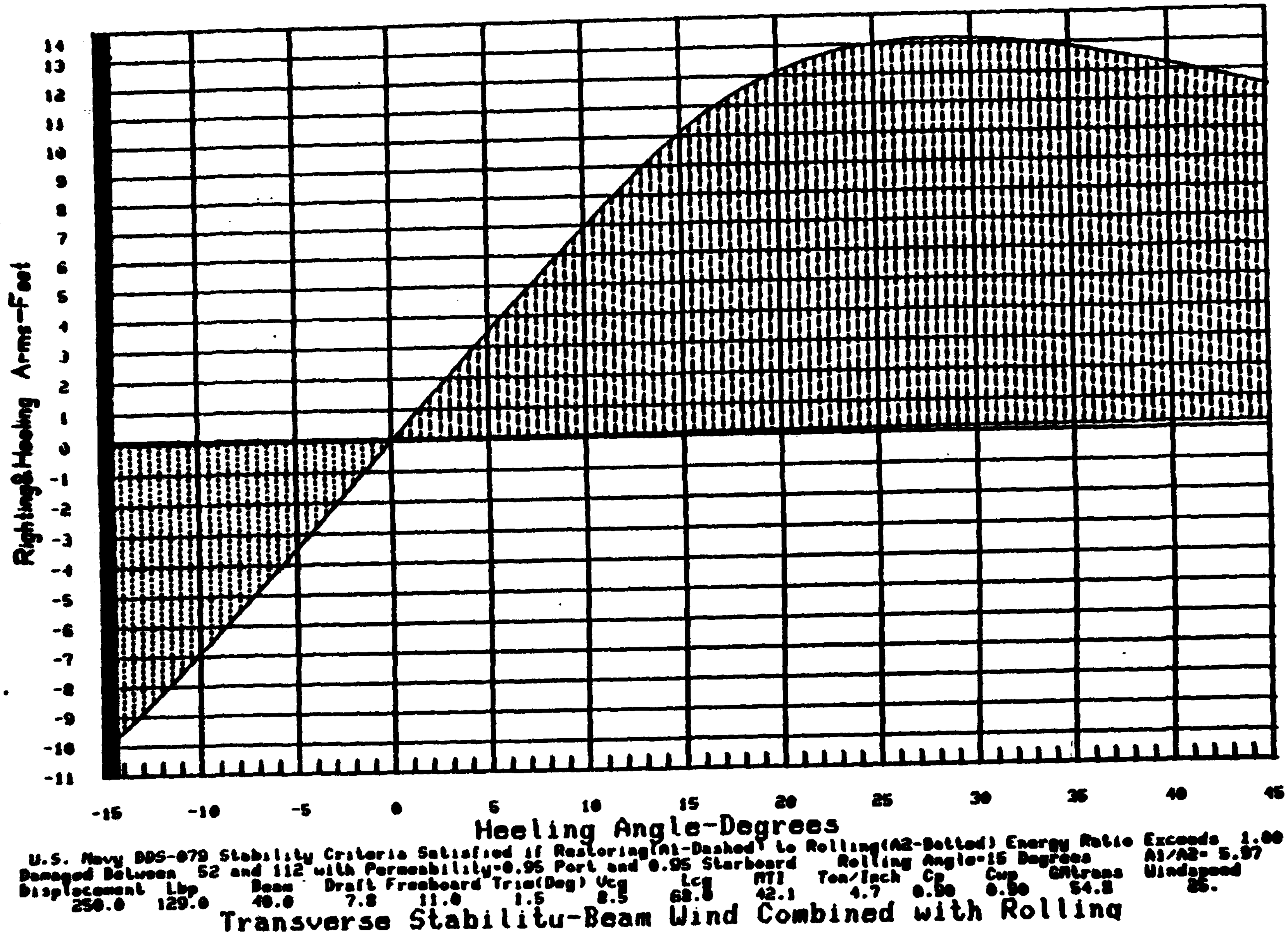


Figure 4.6-22. WPC-SES Damage Stability Compartments 4 and 5, Shell-to-Shell Damage

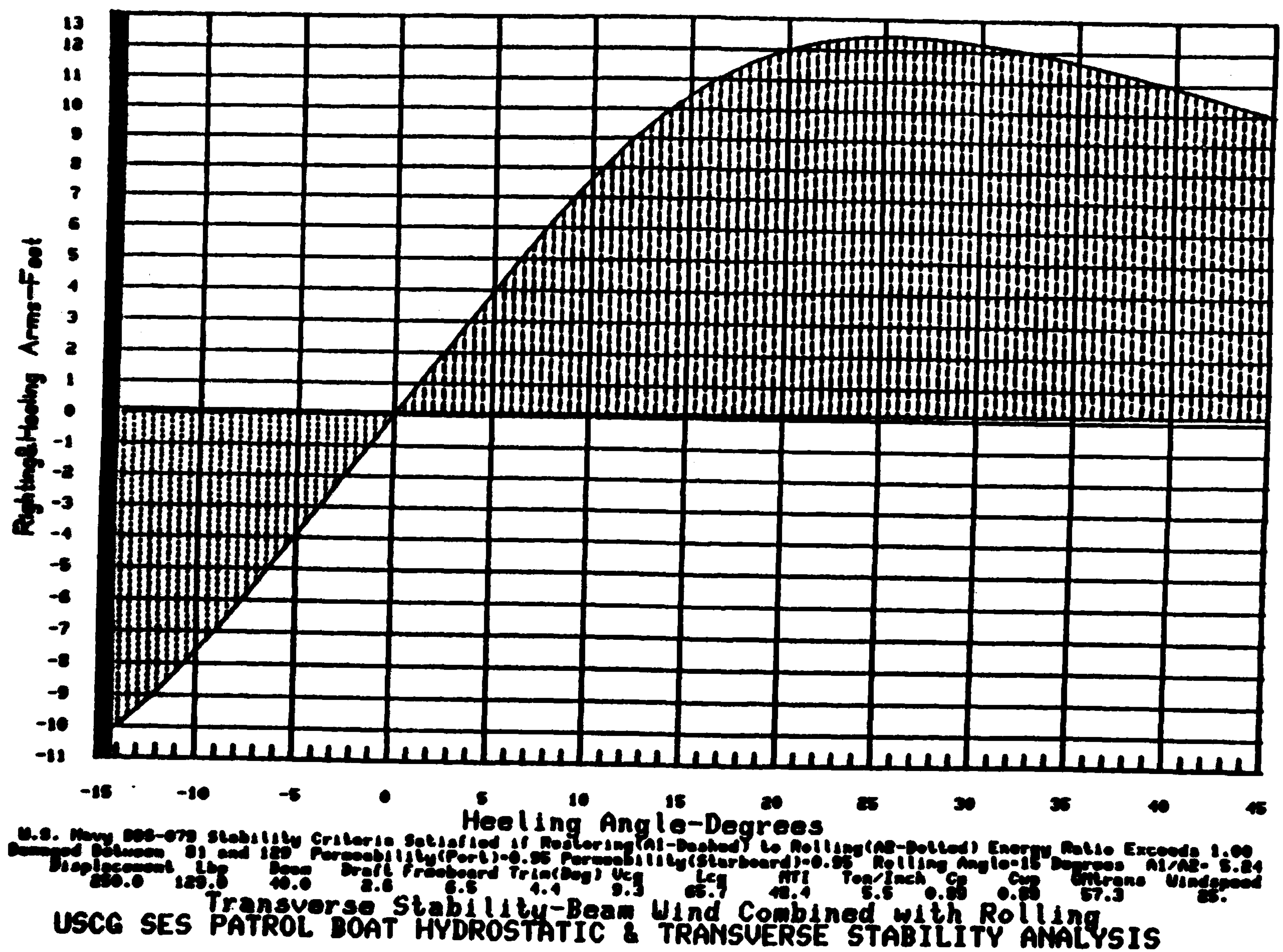


Figure 4.6-23. WPC-SES Damage Stability Compartments 5 and 6, Shell-to-Shell Damage

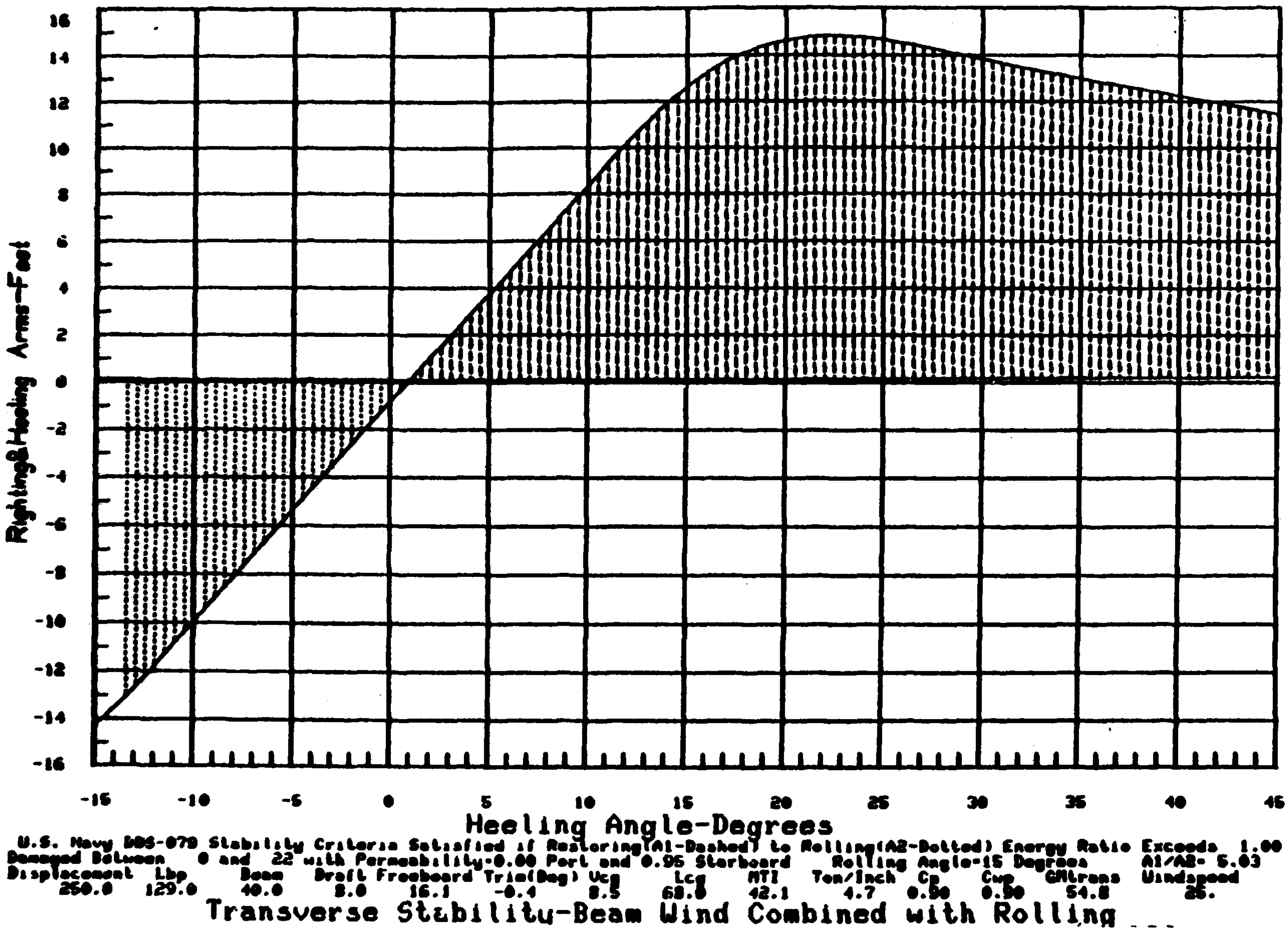
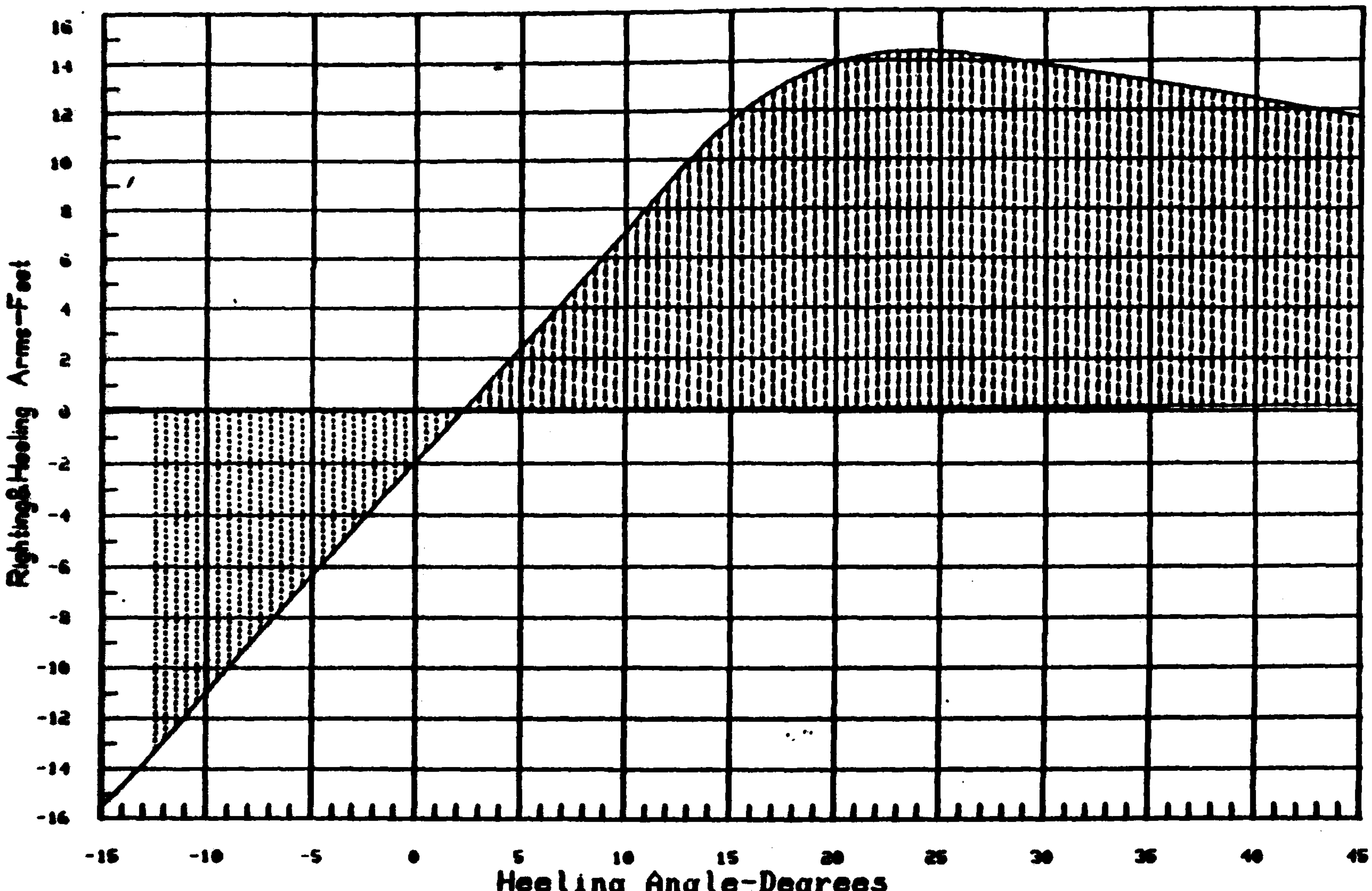


Figure 4.6-24. WPC-SES Damage Stability Compartments 1 and 2, Damage to Centerline



U.S. Navy DDS-079 Stability Criteria Satisfied if Restoring(A1-Dashed) to Rolling(A2-Dotted) Energy Ratio Exceeds 1.00
Damaged Between 14 and 52 with Permeability=0.00 Port and 0.95 Starboard Rolling Angle=15 Degrees A1/A2= 4.73

Displacement	Lbp	Beam	Draft	Freeboard	Trim(Deg)	Vcg	Lcg	MT1	Ton/Inch	Cp	Cwp	GMtrans	Windspeed
250.0	129.0	40.0	8.1	16.1	-0.3	8.5	68.8	42.1	4.7	0.90	0.90	54.8	85.

Transverse Stabilitu-Beam Wind Combined with Rolling

Figure 4.6-25. WPC-SES Damage Stability Compartments 2 and 3, Damage to Centerline

Figure 4.6-26. WPC-SES Damage Stability Compartments 3 and 4, Damage to Centerline

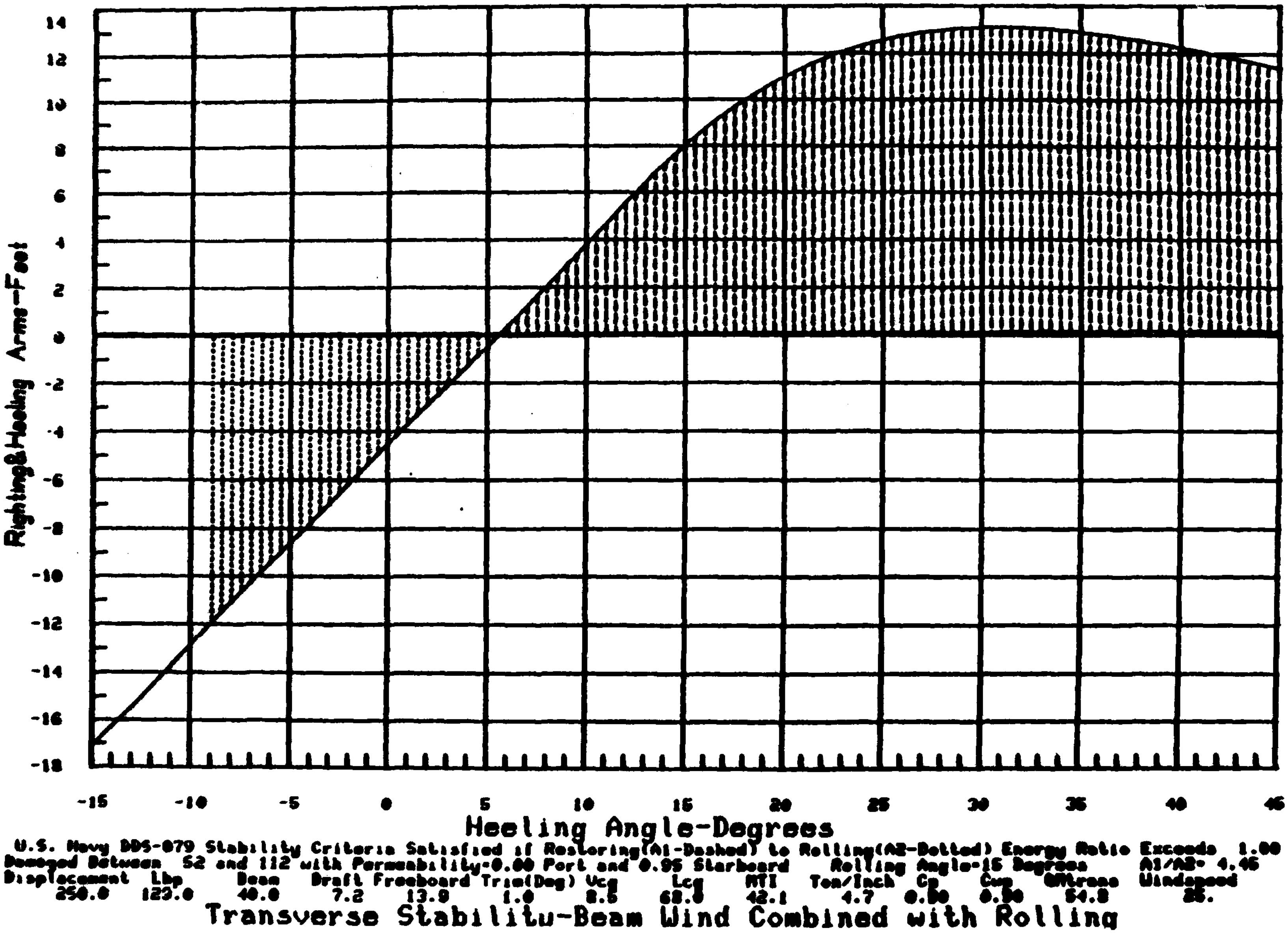


Figure 4.6-27. WPC-SES Damage Stability Compartments 4 and 5, Damage to Centerline

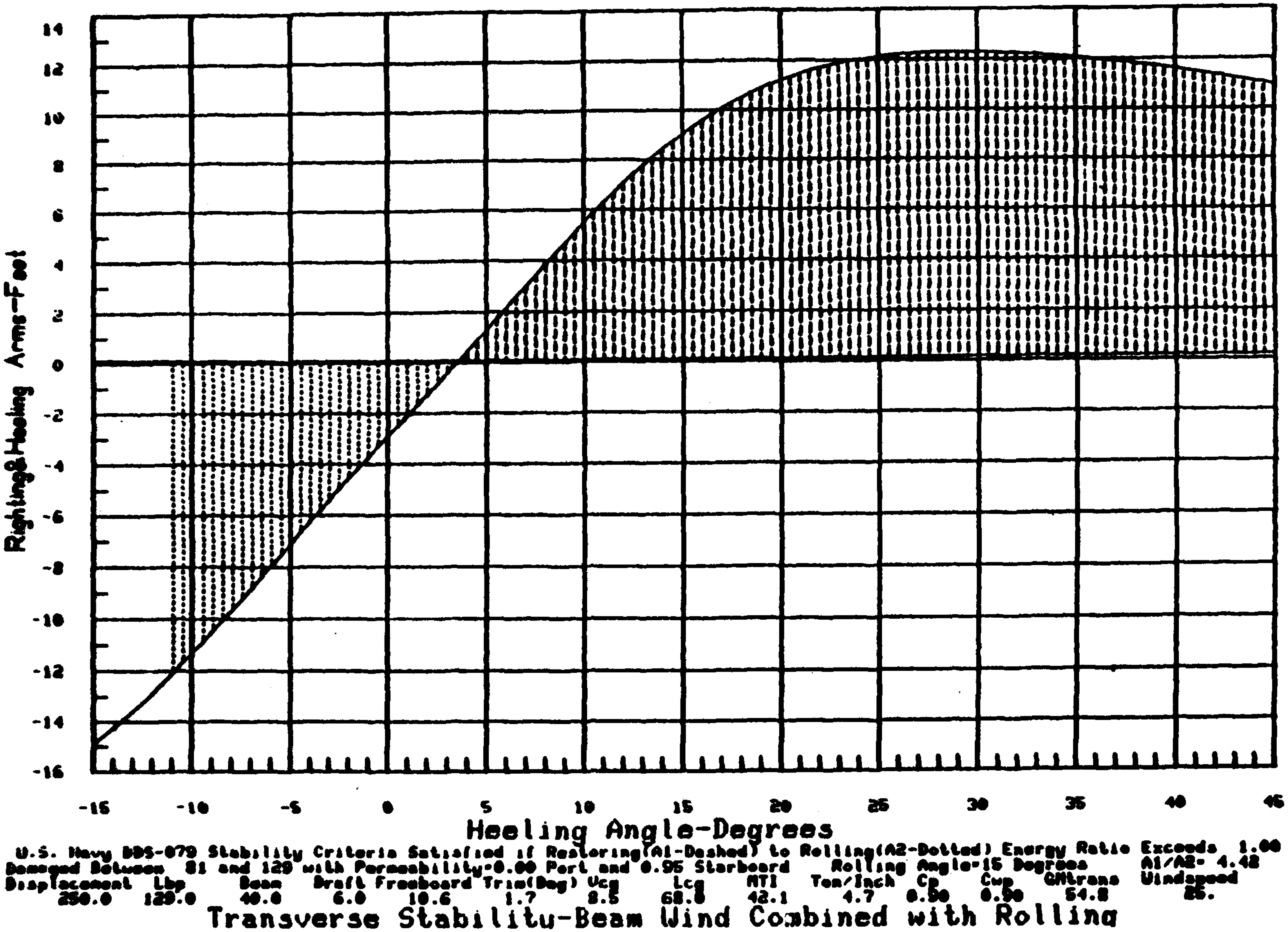


Figure 4.6-28. WPC-SES Damage Stability Compartments 5 and 6, Damage to Centerline

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